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Vol. 118

PETROLEUM DEVELOPMENT AND TECHNOLOGY

1936

PETROLEUM DIVISION

PAPERS AND DISCUSSIONS PRESENTED BEFORE THE DIVISION AT HOUSTON, TEXAS, OCT. 10–12, 1935 AND AT NEW YORK, FEB. 17–21, 1936.

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LETTER OF TRANSMITTAL

Mr. A. B. Parsons, Secretary
American Institute of Mining and Metallurgical Engineers
29 West 39th Street
New York, N. Y.

Dear Sir:

I take pleasure in transmitting herewith TRANSACTIONS, Petroleum Development and Technology, 1936, containing papers and production statistics presented at the fall meeting held in Houston, Texas, and the annual meeting, held in New York. Space does not permit the inclusion herewith of all papers presented at these meetings, but reference is made in the Contents to papers presented but published elsewhere.

The Houston meeting featured a symposium on estimation of oil reserves. While many new aspects of this subject were presented, new problems have been presented from year to year, and the future will undoubtedly demonstrate that much remains to be solved in this field. The papers dealing with the various phases of production and research engineering cover the newer developments over a wide geographical area in the United States. One paper was contributed from abroad. It is significant that the papers afford a practical answer to many current problems confronting the oil-producing industry today.

The economic sessions at the annual meeting were concerned mostly with the need of finding more oil reserves throughout the world. The role of drilling in the functioning of proration, marketing conditions and oil regulation were also included in the list of topics inciting unusual interest. The papers on production statistics are proving to be of increased usefulness, as witnessed by the marked upswing in demand for the later editions of the annual volume.

It is with pleasure that I express the appreciation of the Petroleum Division to the officers of the Institute for the many valuable suggestions on programs and general routine. The fine cooperation of fellow officers of the Petroleum Division, which has made this volume of technical papers possible, is also greatly appreciated. It has been a privilege to work with those whose perseverance guarantees the future welfare of the Petroleum Division and its value to the industry.

Respectfully submitted,
H. H. POWER, *Chairman*,
Petroleum Division, 1935.

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PLANS FOR PETROLEUM DIVISION IN 1936–37

By H. N. Marsh, Chairman of Division

The officers and staff of the Petroleum Division are the servants of the members, and to the extent that the wishes of the members are made known and are practicable they will be carried out. The tentative plans outlined here are in general accord with previous custom, but modified by suggestions received recently from various members. The advice of all members is solicited, and it is hoped that the general expression on matters of policy can soon be facilitated by circulation of a questionnaire.

Plans for two mid-year meetings of the Petroleum Division and for participation in the annual meeting at New York were inaugurated at the last annual meeting and are being carried forward as rapidly as possible in the belief that an early start will increase the possibility of finding the best available program material and permit the careful preparation, review, editing, and advance discussion of papers. While a number of papers have already been solicited, both members and nonmembers are hereby invited to submit additional papers, with the assurance that such papers will be given just as favorable consideration as the papers that have been requested.

Mid-year meetings will be held at about the same time both in the Mid-Continent and California. The time will be selected if possible to coincide with the visits of President Lovejoy, who expects to be in California the last of September and in Texas early in October. Fort Worth, Dallas and Austin have been suggested for the Mid-Continent meeting. The Pacific Coast meeting will be held at Los Angeles. It is to be noted particularly that a Pacific Coast meeting was waived last year in favor of the annual meeting of the American Petroleum Institute, which was held at Los Angeles for the first time in nine years. It is hoped, and it was the understanding at the time among a number of individuals interested in both organizations, that in view of this action of the Petroleum Division the industry will give more than the usual support to the A.I.M.E. meeting this year.

Ultimate Recovery is being considered as the keynote topic for the mid-year meetings. In view of trying financial conditions combined with an exceptionally high current potential *rate* of production, it is natural that the attention of the industry should be focused upon means of controlling production and reducing cost of operation. It seems that the Petroleum Division of the A.I.M.E., as a professional group, might

well recognize that despite excessive current potentials, reserves of petroleum are finite and that all reasonable means of increasing ultimate recovery should be investigated and encouraged. This does not mean that, to be acceptable, papers must be confined to this general topic: papers on any subject pertaining to petroleum production will be welcomed, but papers on the selected subject and the indirect bearing of other subjects on it will be given special attention.

The tremendously valuable work of the Committees on Economics, Production and Stabilization will be continued and given all possible support. However, a number of members have pointed out that while engineers as individuals should be interested in every subject of importance to the industry by which they are employed, they belong to the American Institute of Mining and Metallurgical Engineers primarily for the purpose of receiving engineering material. With this comment in mind, efforts will be made to secure more than the usual number of papers upon strictly engineering subjects.

An effort will be made during the year to make Mining and Metallurgy more interesting to members of the Petroleum Division. It is planned to publish at least one major oil article in each issue, also to develop for the magazine short comments or discussion on technical subjects by men familiar with what is going on in the field. It is thought that in time these items may be made up into a special department.

Will the members please advise their officers regarding any desired modification or amplification of this program?

THE ANTHONY F. LUCAS GOLD MEDAL

The Institute has this year established the Anthony F. Lucas Gold Medal, which will be awarded from time to time "for distinguished achievement in improving the technique and practice of finding and producing petroleum." These awards will be sponsored by the Petroleum Division.

As a board of award, President John M. Lovejoy has appointed the Lucas Petroleum Medal Committee, consisting of: F. Julius Fohs, E. G. Gaylord, Paul Weaver, until February, 1937; Hallan N. Marsh, Russell S. McFarland, John R. Suman, until February, 1938; R. Ogarrio, H. H. Power, Carl A. Young, until February, 1939; E. DeGolyer, W. B. Heroy, C. V. Millikan, until February, 1940. Ex officio members are: Ralph D. Reed, Axtell J. Byles, John M. Lovejoy, presidents, respectively, of the American Association of Petroleum Geologists, the American Petroleum Institute, and the A.I.M.E., and John Wellington Finch, Director of the U. S. Bureau of Mines. Mr. DeGolyer is the Chairman. It is expected that the first medalist will be selected in 1936, so that the presentation can be made at the annual meeting of the Institute in 1937.

Captain Lucas was a pioneer in the oil industry, one of the early wildcatters and a leading mining and petroleum engineer. He was famous as the discoverer of Spindletop. He became a member of the Institute in 1895 and in 1913 was the first Chairman of the Petroleum and Gas Committee of the Institute, the forerunner of the present Petroleum Division. He also headed the Committee in 1914, 1917 and 1918.

Chapter I. Estimation of Petroleum Reserves

Estimation of Developed Petroleum Reserves

By M. Albertson,* Member A.I.M.E.

(Houston Meeting, October, 1935)

The purposes of this statement are to define a problem that exists in regard to the estimation of developed petroleum reserves, to analyze the problem in an abstract manner, and to discuss it as an introduction to certain papers that follow. The problem is to devise and develop a suitable procedure to permit more accurate estimates of developed petroleum reserves. Part of the problem is to make such estimates available earlier in the life of any particular pool.

The problem of securing more accurate estimates of developed petroleum reserves existed prior to curtailment of production. With curtailment, however, the problem became acute, some of the more prominent reasons being as follows:

1. The standard method of estimation depended on production-decline curves. This method is inapplicable while curtailment prevails and available methods are insufficient.

2. The retarding influence imposed by wide open flow conditions upon overdevelopment is absent. Great losses of capital by overdevelopment can now occur before realization of the true situation occurs, or before effective steps can be taken to stop such wastage. This increases the need for early, accurate estimates.

3. Above-ground stocks have diminished and the equivalent of such supply tends more and more to be retained underground in the natural reservoirs. It becomes increasingly necessary to know accurately the amount of these stocks.

To direct attention to an additional point of different nature: improved accuracy of reserve estimation can be obtained only by closer scrutiny of the factors that determine recovery. This examination and the resulting efforts to measure the effect of these factors in terms of ultimate recovery must tend to improve ultimate recovery.

The statements regarding the acute nature of the problem also indicate to some extent the importance of the problem and the necessity of finding a solution. Developed reserves of the industry, and of individual operators, are one of the great factors that properly should determine explora-

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* Research Engineer, Shell Petroleum Corporation, Houston, Texas.

tion and development policy. It is obvious that the importance of a solution would justify great effort.

The engineer responsible for advising his company will do well to keep in mind the recommendation of slow orderly development and the accumulation of the maximum information early in the pool's life as a sound policy to adopt and insist upon. A sound estimation of reserves cannot be made unless complete information is obtained from the start and a sound development and production policy is not possible without analysis of such data. If mistakes are made in this phase of a field's history, the engineer advising will bear the brunt of them regardless of who made the decision that developed into errors.

Volumetric Method

Since the decline-curve method became inapplicable, the volumetric has become the chief method. It depends on the factors of productive formation volume, porosity, saturation and ecovery. The increased efficiency of core recovery, the standardization of porosity determinations and the use of electrical logging devices permit rather close and accurate determinations of the first three of these factors. Geological assumptions of conditions existing between points of known conditions can be made that will be acceptable as to accuracy by all but the supercritical. Relative reserves for tracts within the usual type of sand reservoir, and many others as well, offer no particular problem to current methods, as cancellation of the recovery factor permits comparative determinations with suitable accuracy. Thus the estimation of comparative reserves of various tracts, as required for proration purposes, can now be readily accomplished with acceptable accuracy. This has been fully demonstrated by experience. In proration problems, the task of reserve estimation is greatly simplified and opportunity to assure accuracy is given by periodical changes in allocation. Comparative estimates, while of interest in connection with the problem here discussed, are essentially not a part of the problem. Estimates of absolute quantity constitute the problem. This requires determination of the recovery factor. We then have to deal with the actual value of the recovery factor and its determination at different stages of the pool's producing life. A summation of the present accuracy of the determination of this factor may be stated as follows:

1. When but one or two wells have been drilled—qualitative.
2 When some production has been taken from the pool and its approximate outlines are known—semiquantitative.
3. When the reservoir reactions are susceptible of accurate measurement—quantitative.

At the last stage of estimates, the predictions of reserve should be within plus or minus 10 per cent correct for the prevailing conditions.

Weaknesses in Methods of Estimation

Broadly considered, methods of reserve estimation and the data for such estimates have never been sufficient to meet the full need for accurate estimates. Some weaknesses of the decline-curve method were:

1. Only an average expectation could be forecast. The actual recovery usually varied considerably from the estimated amount.
2. Decline-curve methods cannot be applied to a particular field, with satisfactory assurance, until a substantial part of the producing life of the field has passed. Thus, during the development period, when accuracy is most required, the method is weak.
3. Decline-curve methods do not include, in any satisfactory manner, the influence of changes in production technique.

The chief weakness of the volumetric method has already been indicated as determination of the recovery factor. The difficulty of determining the saturation factor also warrants close attention. Under some conditions, determination of the recovery factor may make the use of a saturation factor unnecessary.

Increasing Accuracy of Methods of Estimation

The problem is to bring the art of reserve estimation to a higher plane of development. Thorough consideration must include every factor that influences petroleum recovery. There are thus included effects of future changes in the technique of petroleum extraction. The problem includes the entire technique of petroleum recovery methods, and also the parts of the legal, political and economic fields that influence the technique of petroleum recovery. An instance of profound change by these outside influences is found in the recent one from open flow to restriction. In the old method of producing at capacity, the field early demonstrated its characteristics and the brake could be applied to prevent overdevelopment and economic suicide. At present, with percentage recovery from the field entirely different, as compared to the time interval, errors in policy are not so readily evident early in the pool's life; therefore it becomes more imperative to stop, look and listen before making decisions as to policies.

Looking backward for a moment, it may be noted that estimation of reserves by the method of production-decline curves was a procedure whereby a portion of the declining rate of production from one or more wells was mathematically treated so as to indicate future recovery. The method became suitable for general use only after assembly of volumes of data. The rate-of-decline method sums up the total effect of all factors that have influenced recovery. It is thus a short-cut method. Is it possible to find a suitable method of measuring one or more significant groups of factors while operating at curtailed rates?

We must find the quickest possible accurate determination of the recovery factor. Efforts directed to this end are being made and may prove of material assistance even if no complete integrating step is found possible. Judging from past improvements along this line of endeavor, we may expect to see the future yield the answer at a much earlier date than would be expected at present.

Since quantity of oil recovered is a summation of the quantities due to each factor that influences recovery, under the existing conditions, an effort has been made to list all factors. The list is first made by groups:

A. Quantity of oil in the productive formation.
B. Energy available to move oil to the wells.
C. Loss of energy other than in movement of oil.
D. Efficiency with which energy is consumed in movement of oil.
E. Loss of oil and gas due to leakage from the reservoir.

Each of these groups of factors may be elaborated as follows:

A. Quantity of oil in the productive formation depends on:
   1. Volume of the reservoir rock.
   2. Porosity.
   3. Saturation.

B. Energy available to move oil to the wells:
   1. Energy of gas, oil, and water, due to pressure:
      a. Without expansion.
      b. By expansion of each fluid.
   2. Energy of gravity acting directly.
   3. Molecular energy of gas, oil, and water, to displace oil from reservoir rock.
   4. Artificially supplied energy.

C. Loss of energy other than in moving of oil to the wells:
   1. Escape of gas, oil, and water pressure without oil recovery.
   2. Gravity may move oil from the wells as well as to them.
   3. Escape of gas and water without exerting their molecular energy to move oil.
   4. Energy made unavailable due to loss of heat in reservoir, by solution reactions and changes of state.

D. Efficiency with which energy is consumed in movement of oil:
   1. Well spacing.
   2. Rate of oil recovery.
   3. Permeability of sand (shooting, acid treatment, mudding).
   4. Gas-oil ratio.
   5. Water-oil ratio.
   6. Locus of gas, water and oil expansion.
   7. Viscosity of oil.
   8. Specific heat and latent heat.
   9. Molecular energy.

E. Loss of oil and gas due to leakage:
1. Poor quality of casing.
2. Normal corrosion of casing.
3. Improper casing methods.
4. Entrance of surface water.

Although the factors may be arranged in five groups, the total number of factors is large. Enumeration of the factors and their classification into groups of factors is sufficient to suggest strongly that if accurate estimation of developed reserves has to await quantitative determination of all factors, it will never be possible. If this is true, hope of satisfactory estimates depends on finding the relationship between recovery and one or more groups of significant factors, which may be readily determined. Below are some suggestions for exploration:

1. Fractional part of total energy consumed per unit of oil recovery.

2. Determination of oil recovery per unit retreat of oil from oil reservoir plus more accurate estimation of reservoir size and content. (Water surveys, gas surveys, electrical logging of formations, better core recovery, etc.)

3. Rate of reservoir pressure decline per unit of oil recovered, and influence of rate of recovery upon total recovery.

4. Oil recovery per A.P.I. gravity unit under reservoir conditions of temperature and pressure.

5. Average gas-oil ratio and rate of variation per suitable time unit for life of field.

6. Combinations of the above factors pertinent to the particular field.

The scope of this paper is necessarily broad in nature and the factors suggested and discussed briefly are complex. It is probable that many of them can be investigated at the same time and their results expressed in terms of each other. Common effort is necessary to make the advances essential to solve field-wide problems and since specific problems to which answers are obtained without the effect of contributing factors being known are subject to grave error, it is imperative to have complete operator cooperation in collecting and analyzing data from any pool. Today, the engineer finds himself being challenged by the industry to advise it as to what path to follow in new development and it behooves the engineer to fully advise the industry what it must do to cooperate with him and permit him to arrive at sound conclusions. We must not permit our work to be classified as black magic or glorified guesses, but we must admit our shortcomings and intelligently attack the problems confronting us.

Acknowledgments

The writer is particularly indebted to F. E. Heath for assistance and criticism. Valuable suggestions have also been received from C. E. Reistle, Jr., and T. V. Moore.

A Method of Estimating Oil and Gas Reserves

By D. L. Katz,* Junior Member A.I.M.E.

(Houston Meeting, October, 1935)

In the management of oil properties, it is always desirable to know the future behavior of oil wells and oil reservoirs. Some estimation of the quantity of oil and gas that will be produced must be made as a basis for decisions on possible returns on investments in lifting equipment, drilling of additional wells, and other operating expenditures. In new or wildcat areas, operating expenditures are considered highly speculative, but in the completion of partly drilled and the operation of producing fields it is good business to remove as much speculation as possible. An accurate knowledge of oil and gas reserves in such cases would solve many management problems.

The term "oil reserves" usually signifies the future ultimate recovery without specifying the method of production. Thus with changing methods and innovations in the production industry, reserves of any definite reservoir may be increased by increasing the portion of oil recovered. The usual reserve estimates are made by comparisons of well and formation characteristics, by using a percentage recovery on the oil content of the formation volume using porosity data, by extending production curves on non-prorated wells, or by extending bottom-hole pressure-production curves. The most reliable method would appear to be one that would estimate the initial quantity of oil and gas present and then obtain percentage recovery values for various productive methods and formations from experience.

It is the purpose of this paper to describe a method of estimating the initial quantity of oil and gas present in a reservoir. The method is based on field operating data and the properties of crude oil-gas mixtures. The principles involved, the data required, the assumptions necessary, and an example of the method will be given. The method is entirely independent of sand volumes and formation porosities.

Principles of Method

The method of estimating the initial quantity of oil and gas present is based upon the premise that the volume occupied by oil and gas in the reservoir is constant and that a mixture of crude oil and gas will behave in

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* Phillips Petroleum Co., Bartlesville, Okla.

the same way in the reservoir as in the laboratory under similar conditions of temperature and pressure. The pressure on a sample of reservoir oil is released in the laboratory and the quantity of gas evolved is measured. These data, along with other information, make it possible to use the field oil and gas production quantities and reservoir pressures to predict the quantity of oil that must be present in the reservoir to cause the observed maintenance of bottom-hole pressure.

In order to apply the method, the data on the oil and gas production, bottom-hole pressures and properties of the crude oil-gas mixtures are obtained. The crude oil produced gives one portion of the initial crude present. The gas produced in excess to the gas dissolved in the crude at the initial reservoir conditions comes from crude in the reservoir and at a definite number of cubic feet per barrel, as shown by the solubility data and reservoir-pressure changes. Thus this excess gas accounts for a second portion of crude that was present in the reservoir. When the crude and gas are produced from the reservoir, a space is left, which is occupied by gas vaporizing from the crude in the reservoir with a corresponding drop in reservoir pressure. The volume of this space can be calculated as containing a definite quantity of gas that was evolved from the crude at a definite number of cubic feet per barrel. The cubic feet of gas in the gas phase in the reservoir divided by the gas evolved per barrel of oil gives the barrels of crude that must be present to have maintained the reservoir pressure. This third quantity of crude when added to the other two portions gives the total quantity of crude oil that was present initially. The gas present is then calculated from solubility data and the crude-oil quantity.

There are several variations and detailed auxiliaries in this method of arriving at the quantity of oil and gas present. When the initial quantity of oil is determined it is possible to estimate the change in reservoir pressure for a given production of oil and gas. A paper[1*] given six years ago has been found to be based on the same principles as this paper. It described a mathematical solution of the decline in reservoir pressure with oil and gas withdrawal. The formula presented required the assumption that the solubility curve is a straight line through the origin, it neglected the deviation of the reservoir gases from ideal gas laws, and does not appear to give results comparable with this method.

Assumptions Involved

The major assumption is that the volume of the pore space in the reservoir occupied by gas and oil is constant. In a reservoir with a slow water drive, the method is applicable if the decrease in volume of pore space due to the water encroachment is known over a period of time.

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* References are at the end of the paper.

Also, the calculations may be made neglecting the water encroachment and noting the changes in amounts of initial crude calculated over various times in the life of the pool. This method is not expected to be of any value on pools that are under true water drive, such as East Texas.

One assumption that must be made is that the reservoir initially was filled with liquid or that a definite quantity of the reservoir contained gas. In this respect the method is similar to the sand-volume porosity method. If a gas cap is present and the volume of the reservoir initially filled with gas is known, it can be treated independently and will cause no difficulties.

When applying laboratory data to the reservoir, one might say the assumption is made that the oil and gas behave in the laboratory as they do in the reservoir under similar conditions of temperature and pressure. However, the duplication of laboratory results on a sample should be proof that this is a fact and not an assumption.

In the gathering of data such as bottom-hole pressures, quantities of oil and gas production, and deviation of gases from the ideal, often some of the data are not taken; then it is necessary to interpolate or extrapolate data to approximate these values. The bottom-hole pressures as measured should be representative of the entire reservoir volume and it is necessary to assume that the bottom-hole pressures taken in the wells are representative of the reservoir, or measurements must be corrected to an estimated average pressure.

Data Required

The data required for calculating the initial quantity of oil and gas present in a reservoir are bottom-hole temperatures and pressures, oil and gas production figures, solubility and shrinkage curves of the reservoir crude oil, and deviation of reservoir gases from the ideal gas laws.

Bottom-hole Pressure and Temperature data are taken on most pools at the present time but these data are not always available on older pools. The important pressures are the initial pressure of the pool and the pressure as of some date at which the accumulated oil and gas production figures are available. The average temperature of the pool must be determined but it is not usually expected to vary materially over the life of the pool. As mentioned previously, the bottom-hole pressures are expected to be representative of the reservoir pressure and should be compiled with this idea in mind.

Oil and Gas Production figures must be known from the time the first well was drilled and accumulated to any chosen time in the life of the pool. The oil quantities are recorded in normal cases and should be rather reliable data. However, the gas produced is not always measured, nor is it usually recorded for a pool. In these cases it is necessary for an operator to measure as many gas-oil ratios as possible and fill in the

unmeasured ratios according to the test information available. As gas withdrawals are pertinent to decline in bottom-hole pressure, it would seem that the industry would soon place gas-volume figures on a similar status with crude-oil records. The quantities of oil and gas produced when plotted against average reservoir pressures are expressed in a suitable form for use in the method.

Solubility and Shrinkage curves are needed to estimate the initial oil and gas present in the reservoir. The most desirable way to secure these data is to obtain a sample of reservoir crude under the initial reservoir pressure by some method such as described by Lindsly[2] or Schilthuis[3] and differentially vaporize the sample at the reservoir temperature. The quantity of gas evolved and the shrinkage of the liquid phase should be noted at various pressure intervals. These data are usually plotted as percentage shrinkage and solubility of gas in cubic feet per barrel for vaporizing the sample from any pressure down to atmospheric. If the sample of virgin reservoir oil is obtained, the original saturation pressure of the reservoir can be determined. If no sample of reservoir crude is obtained until a pool has produced considerable oil, a sample at the later date will suffice to give solubility and shrinkage data provided the reservoir pressure is still 600 to 800 lb. It happens that both solubility and shrinkage curves approach straight lines above 300 to 500 lb. and so the straight-line portion may be extended to higher pressures with fair accuracy. However, the question of initial saturation pressure is unsolved by analysis of such a sample, but a consideration of the decline curve for bottom-hole pressure and initial gas-oil ratios will give a basis upon which this saturation pressure may be estimated.

It is advisable to obtain several scattered samples of reservoir oil, especially in a large pool, and the solubility and shrinkage results then should be averaged. The method of differential vaporization may be varied, but the method of vaporizing the sample at constant volume of sample[2] is probably as close to reservoir conditions as one may expect to attain.

Deviation of the Reservoir Gases from ideal gases is an important factor in the calculation of the quantity of initial crude in the reservoir. The deviation is needed to augment the ideal gas laws when obtaining the quantity of gas contained in the reservoir in gas or vapor space. No data are available on the deviation of reservoir gases at high pressures and prevailing reservoir temperatures. Johnson and Berwald[4] have reported deviations of pipe-line gases at temperatures of 40° to 80° F. and at pressures up to 1000 lb. per sq. in., giving partial analyses of the gases. Sage, Lacey, and Schaafsma[5] have reported the densities of methane-propane mixtures at temperatures from 70° to 220° F. and pressures up to 3000 lb. per sq. in. Deviations of the mixtures from ideal gases may be calculated from the data.

Either the deviations of the gases must be measured or some method devised that will utilize the data mentioned above, and that on the pure compounds[6,7,8] to give a reliable value for the reservoir gases. An analysis of the reservoir gas at various stages of pressure decline may be obtained by analyzing the gases differentially vaporized or as calculated from crude analyses. One might think that the deviation for the mixture could be obtained by using the analysis of the gas and the deviations

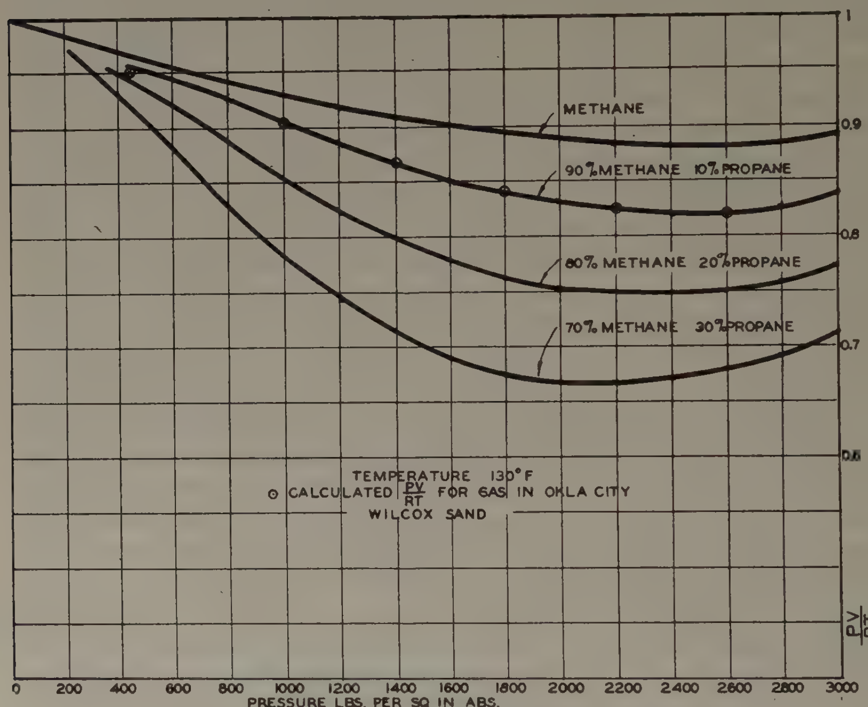

FIG. 1.—DEVIATION OF GASES FROM IDEAL GAS LAWS.

for the constituents. The methane-propane data show that if the deviation of the pure methane is used to calculate the volume of the propane in a mixture, the propane appears under some conditions to have a negative volume at high pressure.

A method of calculating the deviation has been devised which, although later it may be proved to be unreliable, is at the present time the best available. The molecular weight of the reservoir gas is calculated and reconverted into the mol per cent of propane in methane for this molecular weight. The deviation of the reservoir gas is then taken to be the same as that of the corresponding methane-propane mixture at the same temperature and pressure. Fig. 1 shows curves of the deviation of pure methane-propane mixtures[5,6] (90-10, 80-20 and 70-30 mol per cent) all at 130° F. The deviations are greater for gases of higher molecular

weight and at higher temperatures the deviations become smaller. The deviations are expressed as values of $\frac{PV}{RT}$, which is unity for an ideal gas and is convenient to use. The deviation of the gas from ideal is really the difference between unity and $\frac{PV}{RT}$ divided by $\frac{PV}{RT}$.

The only verification of this comparison of deviations for gases is by checking for experimental and calculated values within 0.02 for the values of $\frac{PV}{RT}$ for a reservoir gas at 70° F. and pressures in the range of 1000 lb. per sq. in. A theoretical reason why this method of estimating deviations might be expected to be fairly close but never exact is that hydrocarbon gases have been shown to have similar deviations at similar reduced states[9]. Gases of the same molecular weight might well be expected to have similar critical temperatures and thus the same reduced temperature. As the constituents of a gas change for the same molecular weight, it will have a different critical pressure and thus not be at the same reduced pressure. However, data are required to clarify the reliability of any such method when applied to mixtures.

Application of Method to Oklahoma City Wilcox Zone

The method of calculating the initial crude oil and gas present in the reservoir is demonstrated by a set of examples calculating the initial crude present in the Oklahoma City Wilcox zone. The data required for the calculation were not always obtained by direct measurement; therefore the results may not be unusually consistent for calculations as of different times during the life of the pool. The examples, however, demonstrate a typical problem and the solution.

The assumption of constant volume of the reservoir pore space is known to be fairly accurate, as water has encroached only in a minor degree. The reservoir is assumed to have had no gas cap or free gas at its initial state. There may have been a small gas cap but it was not of any magnitude.

The data needed in the calculations were gathered from various sources. The bottom-hole temperatures were measured as 130° to 132° F. and the bottom-hole pressures were obtained by a volumetric averaging of pressures from key wells tested periodically. The initial reservoir pressure was not measured but it was estimated at 2600 lb. per sq. in. The oil-production figures were taken from state records and the gas volumes were taken partly from measurements and partly from assumed corresponding gas-oil ratios from some wells. The oil and gas production quantities are plotted against bottom-hole pressure on Fig. 2. The solubility and shrinkage curves shown by Fig. 3 were obtained from B. E. Lindsly's data[10] on Oklahoma City crude oils. The highest satura-

tion pressure measured was around 1500 lb. but the straight-line portions of the curves were extended to higher pressures. It should be noted that the shrinkage values are not plotted in the usual manner of percentages based on the saturated sample. The percentage shrinkage based on the

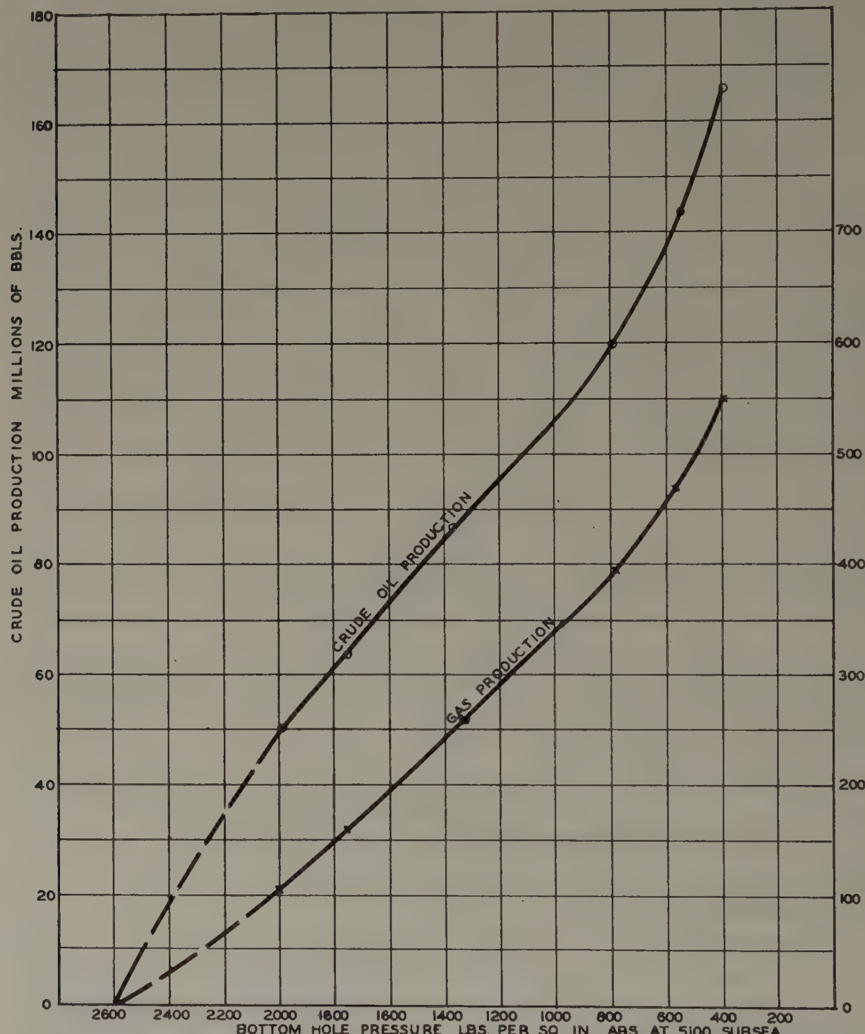

FIG. 2.—PRODUCTION CURVES FOR OIL AND GAS, WILCOX ZONE, OKLAHOMA CITY

residual oil is a more consistent unit and is interpreted as meaning that a shrinkage of 20 per cent is a total of 120 parts liquid and 100 parts residual oil at 60° F.

The deviations of the gases from ideal gases were calculated by the method proposed above. The analyses of reservoir gases were obtained partly from Lindsly's vaporization data and partly from labora-

tory data. The circles approaching the line of 10 per cent propane and 90 per cent methane on Fig. 1 are the deviations calculated for the gases at the various pressures and 130° F. The initial crude present is calculated from the first production down to six different times at intervals of

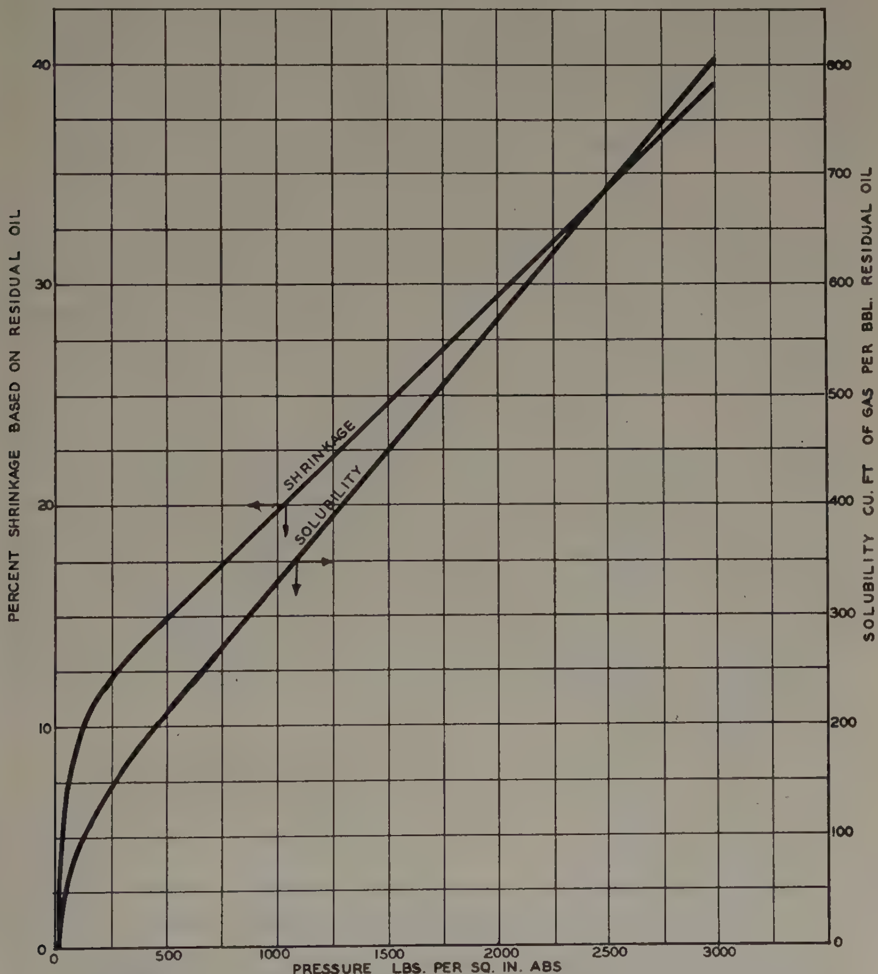

FIG. 3.—SOLUBILITY AND SHRINKAGE CURVES, WILCOX CRUDE, OKLAHOMA CITY.

six months. The dates, pressures, production quantities, other data, and essential calculations are all given in Table 1. Fig. 4 will be used along with a discussion of the various steps in the calculation to illustrate the physical significance of portions of the method.

The solution of the problem is the calculation of the amounts of crude oil required to furnish the crude produced, to provide the gas produced in excess of the gas dissolved in the produced crude, and to provide the gas

entering the vapor space still maintaining the bottom-hole pressure. The vapor space is generally located throughout the reservoir, but when the gas segregates high on a structure it is often referred to as a gas cap.

Columns 1 to 6 inclusive of Table 1 are data taken from the figures. The gas dissolved in the crude oil (column 7) is calculated by multiplying

TABLE 1.—*Calculation of Initial Oil and Gas Content in Oklahoma City Wilcox Zone*

Col. No.		Units	Calculations Made from Reservoir Conditions as of Various Dates					
			7-1-32	1-1-33	7-1-33	1-1-34	7-1-34	1-1-35
1	Crude oil produced	Million bbl.	50.0	65.3	87.5	119.2	144.0	167.0
2	Gas produced	Billion cu. ft.	110.0	163.0	260.0	393.0	480.0	545.0
3	Bottom-hole pressure	Lb. per sq. in.	1990.0	1740.0	1360.0	790.0	545.0	393.0
4	Gas dissolved in crude	Cu. ft. per bbl.	568.0	509.0	420.0	282.0	225.0	188.0
5	Gas evolved	Cu. ft. per bbl.	147.0	206.0	295.0	433.0	490.0	527.0
6	Correction factor for deviation from ideal gases	No units	0.83	0.84	0.87	0.92	0.95	0.97
7	Dissolved gas in produced crude oil	Billion cu. ft.	35.7	46.7	62.5	85.2	103.0	119.0
8	Excess gas produced	Billion cu. ft.	74.3	116.3	197.5	307.8	377.0	426.0
9	Vol. of 1 std. cu. ft. of gas at reservoir conditions	Cu. ft.	0.00699	0.00809	0.0107	0.0195	0.0292	0.0413
10	Vol. produced oil and dissolved gas at res. conditions	Million cu. ft.	380.0	496.0	665.0	906.0	1093.0	1270.0
11	Vol. occupied by excess gas when dissolved in reservoir crude	Million cu. ft.	170.0	266.0	451.0	704.0	861.0	975.0
12	Reservoir vol. of total oil and gas produced	Million cu. ft.	550.0	762.0	1116.0	1610.0	1954.0	2245.0
13	Vol. of gas in the gas cap	Billion cu. ft.	117.7	131.3	132.7	83.5	72.6	57.5
14	Crude necessary to produce gas-cap gas	Million bbl.	801.0	637.0	449.0	193.0	147.0	109.0
15	Crude necessary to produce excess gas	Million bbl.	505.0	564.0	6 9.0	710.0	769.0	808.0
16	Total crude (residual) initially present	Million bbl.	1356.0	1266.0	1205.0	1022.0	1060.0	1084.0
17	Initial volume of gas when dissolved in crude	Million bbl.	477.0	446.0	425.0	360.0	374.0	384.0
18	Initial fluid present in reservoir	Million bbl.	1833.0	1712.0	1630.0	1382.0	1434.0	1468.0

Cubic feet of gas per cubic foot of liquid when dissolved in reservoir crude = 437.0.

Cubic feet of gas vaporized when vaporizing initial crude from 2600 to 14.7 lb. = 715 cu. ft. per barrel.

Percentage of shrinkage based on residual crude when vaporizing initial crude from 2600 to 14.7 lb. = 35.4; i.e., Residual = 100 per cent.

Residual crude = crude at 60° F. that has been vaporized down to 14.7 lb. and 132° F.

the barrels of produced crude by 715, the quantity of gas in solution at the initial condition. Although part of the gas was vaporized by flash, the differences in temperature, etc., make the value of 715 appear to be as reliable an estimate as any. The gas produced minus the gas in solution gives the excess gas (column 8) that was produced but that came from crude in the reservoir. The volume of the produced crude in barrels

multiplied by 5.61 and by 1.354 gives the cubic feet of reservoir space (column 10) occupied by the oil and dissolved gas. This portion of the reservoir is shown graphically in Fig. 4 as *A* and *B*.

The gas produced in excess of the dissolved gas came out of solution from the crude oil. The solubility and shrinkage curves show that 437 cu. ft. of gas at standard conditions are required to make one cubic foot of reservoir liquid. Therefore, the cubic feet of excess gas (column 8) divided by 437 gives the volume (column 11) occupied by the excess gas when it was in the reservoir, section C, Fig. 4. The sum of columns 11

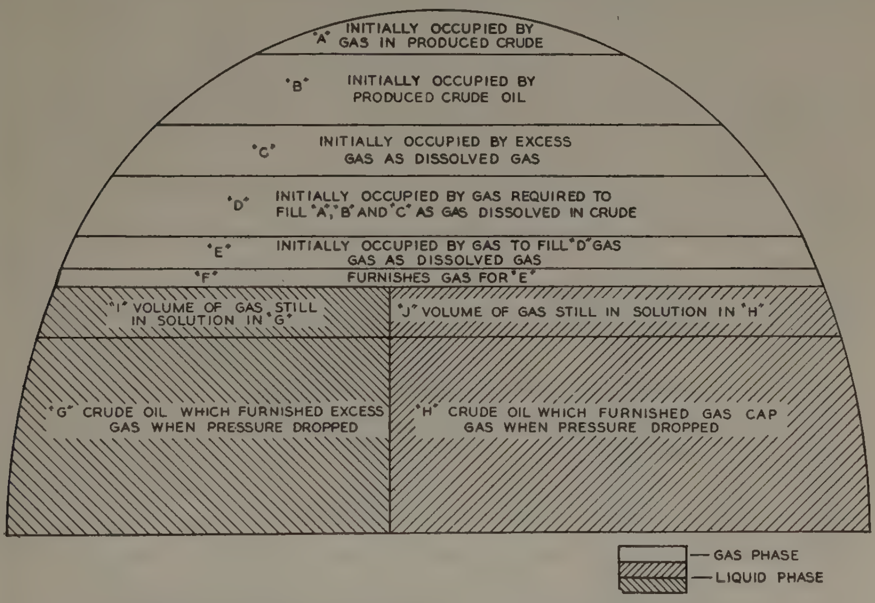

Fig. 4.—Graphic allocation of initial reservoir fluid.

and 10 give the total reservoir volume of the produced oil and gas, column 12.

The next part of the problem is to find the gas present in the vapor phase or in the gas cap. The volume of one standard cubic foot of gas when changed to reservoir conditions is $1 \times \frac{592}{520} \times \frac{14.7}{P} \times \frac{PV}{RT}$. The volumes of one standard cubic foot of gas calculated in this manner are shown in column 9. The volume of gas in the gas cap then is equal to the cubic feet of space vacated by oil and gas produced divided by the cubic feet of space required for one standard cubic foot of gas. In addition to this gas, however, is the gas that goes to fill the space created by the gas going out of solution to fill the gas cap. In addition again is the space caused by shrinkage of crude when giving up the gas going to fill the space created by the first vaporization to fill the gas cap.

This situation can be solved by trial and error but it is of a form suitable to a simple mathematical solution.

Let X = amount of gas in the gas phase in reservoir (std. cu. ft.)

$$a = \frac{\text{volume of produced oil and gas in reservoir}}{\text{volume of 1 std. cu. ft. gas when in reservoir}}$$

b = 437 × volume 1 std. cu. ft. gas when in reservoir.

Then:

$$X = a + \frac{a}{b} + \frac{a}{b^2} + \frac{a}{b^3} \text{ etc.} = \frac{a^*}{\left(1 - \frac{1}{b}\right)} \qquad [1]$$

In Fig. 4, gas a is contained in space ABC, gas $\frac{a}{b}$ is contained in D, $\left(\frac{a}{b^2}\right)$ is contained in E, and $\left(\frac{a}{b^3}\right)$ is contained in F, etc. The solution of the quantity of gas in the gas cap becomes for the first example:

$$\text{Volume of gas in million cu. ft.} = \frac{\frac{550}{0.00699}}{\left(1 - \frac{1}{0.00699 \times 437}\right)} = 117.7$$

Column 13 gives the values for the several examples.

The completion of the problem is simply the division of the excess gas and the gas in the cap by the number of cubic feet contributed by each barrel of crude (column 5) when the pressure was lowered from 2600 lb. down to the then existing reservoir pressure. The crude necessary to furnish 74.3 billion cubic feet of gas at the rate of 147 cu. ft. per barrel is 505 million barrels—represented by section G in Fig. 4. The crude necessary to furnish 117.7 billion cubic feet of gas-cap gas at rate of 147 cu. ft. per barrel is 801 million barrels of crude—represented by section H of Fig. 4.

The total crude oil, in millions of barrels of residual crude, is given by adding columns 1, 14 and 15, or the three contributing factors in the reservoir behavior. The remainder of the space was occupied by gas dissolved in the crude oil. Spaces I and J of Fig. 4 represent the gas still in solution in crude G and H. Column 16 gives the total residual oil, column 17 the total barrels of gas when dissolved in the crude oil as a liquid, and column 18 gives the total fluid initially present in the reservoir.

If the theory and the data were perfect one would expect to calculate identical initial volumes. However, owing to the many variations, the values are not identical but are of the same order of magnitude. The lack of sufficient data in the earlier life of the pool, any possible variation of

* Value of above converging series.

the initial bottom-hole pressure and saturation pressure from 2600 lb., and the possible presence of a small gas cap, all tend to give more credit to the later data. Therefore, a value of 1,050,000,000 bbl. residual oil and 372,000,000 bbl. or 750 billion cubic feet of dissolved gas may be taken as the initial content of the Oklahoma City Wilcox sand.

Prediction of Reservoir Behavior

One of the values of calculating the initial oil content of a reservoir is that the data also may be used to predict the drop in bottom-hole pressure for a given oil and gas production. If these calculations of oil content and pressure decline are made early in the life of the pool, they are particularly valuable in predicting flowing life and probable potential of wells.

For brevity, only an outline of the method of predicting the reservoir pressure will be given. The calculation is based on the same data and logic as the oil-content calculation. The only added assumption to be made is the ratio at which the oil and gas will be produced. By making this assumption for a definite quantity of oil to be produced, at some future date the total accumulated oil and gas production is known. The main equation to be solved is:

(Total reservoir oil − produced oil) × gas evolved from initial saturation pressure down to the predicted pressure equals the excess gas plus the volume of gas in the gas cap [2]

The volume of gas in the cap is equal to the reservoir volume of the produced gas and oil divided by the reservoir volume of one standard cubic foot of gas plus the volume of gas required to fill the space created by vaporization or shrinkage of the crude to provide gas for the first volume plus the gas required to fill this newly formed space, etc. The same equation (eq. 1) may be used to solve the volume of gas present in the cap, but it is necessary to do this for several assumed pressures. The volume of gas in the gas cap and corresponding pressure that will satisfy the main equation[2] gives the reservoir pressure that will exist after the assumed production of oil and gas. This pressure is as accurate as the calculated initial oil content and the assumed ratio of oil to gas.

This rough outline of the procedure could be formulated and a mathematical solution presented. However, because of the complexity of such formulas and of the fact that it is worth while for one to reason the problem through during the solution, no attempt is made to present the problem in this manner. One is much less likely to make gross errors or to attempt a solution without a thorough understanding of the problem being solved when the solution is made in the manner described.

Application to Ultimate Production

A knowledge of the quantity of oil and gas initially present in the reservoir does not specifically answer the question regarding crude-oil reserves. Calculations of this kind and experience should place the crude-oil reserve estimates on a more reliable basis.

The quantity of gas to be produced from a reservoir is fairly accurately determined by the calculations. With the exception of such variations as pulling a vacuum on a reservoir and irregularities in bottom-hole pressure at the ultimate production, the gas produced will approach the total quantity of gas dissolved in the crude above atmospheric or the final reservoir pressure. For instance, an ultimate gas production in Oklahoma City Wilcox of 700 of the 750 billion cubic feet of gas initially present would be considered a fair estimate of the gas reserves.

In using the initial quantity of oil present in the reservoir to predict reserves, a recovery factor similar to the one used in the sand-volume method is the best way known at present. This recovery factor should be stated definitely as meaning recovery of residual crude oil or recovery of initial fluid. Recovery factors in the range of 20 to 40 per cent have been commonly used in estimating reserves. At Oklahoma City, the Wilcox zone has been estimated to have an ultimate recovery of 250 million barrels of oil. Based on 1050 million barrels as the initial crude, this recovery would be 24 per cent based on residual crude. However, the recovery based on the percentage of initial fluid produced would be 43 per cent.

The advantages of making these calculations of initial reservoir fluid over the previous methods are that it gives a reservoir content independent of sand volumes and porosities, which may be so irregular that average values are difficult to obtain. The solubility data and the oil content give the gas reserves directly. An accumulation of data on recoveries in which both the oil and gas measurements have been made and solubility data obtained should give a more fundamental basis for comparing oil recoveries or fluid recoveries from types of formations and by specific methods.

Conclusions

A method of calculating the initial oil and gas content of reservoirs based on oil and gas production data and properties of crude-oil-gas mixtures has been presented and shown to be applicable to the present problems of the industry. The need for gas measurements on producing oil pools is stressed by the place that gas volumes play in the calculations. The initial content of a reservoir gives the gas reserves directly and provides a more reliable method for estimating oil reserves. The application of the described principles allows the calculation of the future

reservoir pressure for a given production of oil and gas. An analysis of an oil reservoir by a method similar to the one described in this paper not only enhances the estimation of oil and gas reserves but gives a clearer understanding of the reservoir and well behavior by virtue of the information made available in solving the problem.

Acknowledgment

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DISCUSSION

(*M. Albertson presiding*)

H. H. Power,* Tulsa, Okla.—I am interested in the estimation of reserves in the Oklahoma City pool, comparing of Dr. Katz's method with the older established methods. Dr. Katz, how do your results check with the porosity saturation method for Oklahoma City?

D. L. Katz.—I am not too familiar with the sand volume-porosity method at Oklahoma City. We have to consider that part of the field is under Oklahoma City and that the only porosity information available is in the data on two Wilcox wells. I believe that the estimates with these considerations give about 600 to 700 million barrels of residual crude oil initially present.

C. E. Reistle, Jr.,† Kilgore, Tex.—In the East Texas field there was no free gas or gas cap in the main reservoir sand system at the time the field was discovered, and as oil has been withdrawn from the field it has been replaced by water. At this time the reservoir pressure in the major part of the field is above the saturation pressure of the oil and gas solution. Therefore, the method discussed by Dr. Katz would not be applicable to the estimation of reserves in the East Texas field.

It would seem questionable to me whether this method could be applied to fields where there is a definite encroachment of water into the oil-saturated part of the sand,

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* Chief Production Engineer, Production Department, Gypsy Oil Co.

† Field Chairman, East Texas Engineering Association.

unless the magnitude of the water encroachment were determined and taken into consideration.

It would also seem impossible to arrive at a satisfactory analysis of the conditions in a field where there is a large variation in the reservoir pressure conditions.

H. H. Power.—Using the Coleman and Wilde formula, we tried to estimate the oil in place in the old Glenn pool. We made several assumptions, including saturation and recovery factors, and came pretty close to the Coleman and Wilde basis of estimation.

Active Oil and Reservoir Energy

By Ralph J. Schilthuis,* Junior Member A.I.M.E.

(Houston Meeting, October, 1935)

In 1929, Coleman, Wilde, and Moore[1] undertook an investigation of the theoretical decline in reservoir pressure as related to the production of oil and gas. The most important part of this work was presented in an equation defining the relationship between the reservoir pressure, the quantities of oil and gas produced, the oil and gas content of the reservoir, and the properties of the reservoir fluids. With this equation, it appeared that, with sufficient data, it would be possible to calculate the oil content of the reservoir and predict quantitatively the effect of gas-oil ratio on the decline of reservoir pressure. Needless to say, such an expression would be highly important in evaluating fields and in arriving at a choice of production methods to be used.

Unfortunately, at the time these investigators published their work, there were not sufficient data available to permit application of the equation. The technique of measuring reservoir pressures had not been developed, gas measurements were uncommon, oil and water production records were in most cases inadequate, and little was known of the properties of the complex hydrocarbon mixtures making up the oil and gas in the reservoirs. For these reasons, little additional work of a similar nature could be done. However, during the past four years many data have been systematically accumulated on reservoir pressures and the properties of oil and gas, and it is now possible to use these data in furthering the studies on the behavior of oil and gas reservoirs.

It is the purpose here: first, to present the derivation of a modified form of the equation given by Coleman, Wilde and Moore, which will permit the calculation of what later will be defined as the "active oil" content of a reservoir; second, to derive formulas for calculating the reservoir-energy changes that occur during the course of production, and finally, to discuss the limitations and application of the equations developed.

Manuscript received at the office of the Institute Oct. 10, 1935.

* Research Engineer, Humble Oil & Refining Co., Houston, Texas.

[1] S. P. Coleman, H. D. Wilde, Jr. and T. V. Moore: Quantitative Effects of Gas-oil Ratios on Decline of Average Rock Pressure. *Trans.* A.I.M.E. (1930) **86**, 174.

Derivation of Equations for Calculation of "Active Oil"

When an oil and gas reservoir is tapped with wells and oil and gas are produced, the reservoir pressure is lowered and the oil and gas remaining are thus caused to expand to fill the space vacated by the oil and gas removed. In connection with this occurrence, it often is the case, where the oil and gas-bearing strata have good connection with strata containing water, that the lowering of pressure in the oil and gas reservoir will cause water to encroach and in effect aid in filling space left vacant by the oil and gas produced. This, of course, decreases the extent to which the remaining oil and gas must expand and accordingly retards the decline in reservoir pressure.

Inasmuch as the temperature in oil and gas reservoirs remains substantially constant during the course of production, the expansibilities, under equilibrium conditions, of the oil and gas remaining in a reservoir are unique functions of pressure, which are determinable through the examination of samples of the oil and gas. The samples[2,3] for such examinations are preferably and most easily obtained under pressure from the bottom of wells. Thus, if the assumption is made that complete equilibrium is at all times attained in reservoirs, it is possible to write an expression relating the quantities of oil, gas and water produced, the reservoir pressure decline attending the production, the quantity of water that may have encroached into the reservoir, and finally the total oil and gas content of the reservoir. These thoughts form the basis for the development of the expressions mentioned in the foregoing. The derivation is as shown in the nomenclature on the next page.

The total volume of the liquid in any oil and gas reservoir under original conditions is the product of the total original number of units (barrels, or cubic feet) of oil, as measured at the surface, by the volume of each unit, with its dissolved gas, as it originally existed in the reservoir:

$$\text{Original liquid volume} = nu_0$$

Similarly,

$$\text{Original free gas volume} = gv_0$$

where g is the original number of units of free gas in the reservoir. Hence, the original volume of the oil and gas reservoir is:

$$V = nu_0 + gv_0 \qquad [1]$$

Now if Δn units of oil be removed, and the specific volume of the remaining oil be changed to u_n, the volume of liquid remaining will be:

[2] B. E. Lindsly: A Study of Bottom-hole Samples of East Texas Crude Oil. U.S. Bur. Mines *R.I.* 3212 (1933).

[3] R. J. Schilthuis: Technique of Securing and Examining Subsurface Samples of Oil and Gas. *Oil & Gas Jnl.* (May 16, 1935).

$$(n - \Delta n)u_n$$

If, at the same time, the free gas in the reservoir has been changed by an amount Δg and its specific volume changed to v, the volume of free gas will be:

$$(g - \Delta g)v$$

The sum of these two quantities is the new volume of the reservoir, which

Nomenclature

Symbol	Definition	Expressed as
p_0	Original average reservoir pressure	Pounds per unit area, absolute
p	Average reservoir pressure at any time θ after production begins	Pounds per unit area, absolute
p_a	Atmospheric pressure	Pounds per unit area, absolute
n	Units of "active oil" originally in reservoir	Volumes, measured at 1 atm. and 60° F.
g	Units of "active free gas" originally in reservoir	Volumes, measured at 1 atm. and 60° F.
m	Original ratio between reservoir space occupied by free gas and that occupied by oil	No units
V	Apparent original volume of reservoir	Volumes, under original reservoir conditions
Δn	Units of oil produced up to time θ	Volumes, measured at 1 atm. and 60° F.
Δg	Change in units of free gas in reservoir up to time θ	Volumes, measured at 1 atm. and 60° F.
Z	Units of water that have entered reservoir up to time θ	Volumes, measured at 1 atm. and 60° F.
z	Units of water produced up to time θ	Volumes, measured at 1 atm. and 60° F.
r	Gas-oil ratio, produced	Volumes gas per volume oil, measured at 1 atm. and 60° F.
r_0	Gas-oil ratio, originally dissolved	Volumes gas per volume oil, measured at 1 atm. and 60° F.
r_s	Gas-oil ratio, dissolved at time θ	Volumes gas per volume oil, measured at 1 atm. and 60° F.
r_i	Gas-oil ratio, returned to reservoir	Volumes gas per volume oil, measured at 1 atm. and 60° F.
r_n	Gas-oil ratio, net produced	Volumes gas per volume oil, measured at 1 atm. and 60° F.
u_0	Original specific volume of oil and its original complement of dissolved gas	Volumes, under original reservoir conditions per volume of oil at 1 atm. and 60° F.
u	Specific volume of oil and its originally dissolved gas at any time θ	Volumes, under reservoir conditions per volume of oil at 1 atm. and 60° F.
u_a	Specific volume of oil and its originally dissolved gas at 1 atm. and reservoir temperature	Volumes, at 1 atmosphere and reservoir temperature per volume of oil at 1 atm. and 60° F.
u_n	Specific volume of oil (one phase) at any time θ	Volumes, under reservoir conditions per volume of oil at 1 atm. and 60° F.
v_0	Original specific volume of free gas	Volumes, under original reservoir conditions per volume of gas at 1 atm. and 60° F.
v	Specific volume of free gas at any time θ	Volumes, under reservoir conditions per volume of gas at 1 atm. and 60° F.
v_a	Specific volume of free gas at 1 atm. and reservoir temperature	Volumes, at 1 atmosphere and reservoir temperature per volume of gas at 1 atm. and 60° F.
θ	Time after production begins	Days or months
ΔE	Reservoir energy consumed up to time θ	Unit length times pounds

is equal to the original volume less the volume of any water that may have encroached into the reservoir:

$$(n - \Delta n)u_n + (g - \Delta g)v = V - (Z - z) \tag{2}$$

where:

Z = volume of water that may have encroached into the reservoir, and

z = volume of water produced

Subtracting equation 1 from equation 2:

$$-n(u_0 - u_n) = u_n\Delta n + v\Delta g - g(v - v_0) - (Z - z) \tag{3}$$

The term Δg is the change in the number of units of free gas in the reservoir. It may be divided as follows:

1. The free gas produced, $\Delta g_1 - \Delta g_2$, where Δg_1 is the total gas produced, and Δg_2 is the dissolved gas produced.
2. The gas escaping from solution in the oil remaining, Δg_3.
3. Any gas that may be returned to the reservoir, Δg_4.

Then:

$$\Delta g = \Delta g_1 - \Delta g_2 - \Delta g_3 - \Delta g_4 \tag{4}$$

But:

$$d(\Delta g_1) = rd(\Delta n)$$

where r = produced gas-oil ratio,

$$d(\Delta g_2) = r_s d(\Delta n)$$

where r_s = dissolved gas-oil ratio,

and $d(\Delta g_3) = (n - \Delta n)d(r_0 - r_s) = -(n - \Delta n)dr_s$ and $d(\Delta g_4) = r_i d(\Delta n)$

where r_i = injected gas-oil ratio.

Therefore:

$$\begin{aligned} d(\Delta g) &= rd(\Delta n) - r_s d(\Delta n) + (n - \Delta n)dr_s - r_i d(\Delta n) \\ &= r_n d(\Delta n) - d(r_s \Delta n) + ndr_s \end{aligned}$$

where r_n = net gas-oil ratio.

Integrating between the limits of the original and final conditions,

$$\Delta g = \Delta n(r_n - r_s) - n(r_0 - r_s) \tag{5}$$

or,

$$\Delta g = \Delta n(r_n - r_0) - (n - \Delta n)(r_0 - r_s) \tag{6}$$

The number of units of gas released from solution from one unit of oil, multiplied by its specific volume, is the volume of the gas released. This is equal to the volume of the mixture of oil and its released gas minus the volume of the oil:

$$(r_0 - r_s)v = (u - u_n)$$

or,

$$(r_0 - r_s) = \frac{(u - u_n)}{v} \tag{7}$$

From equations 6 and 7,

$$v\Delta g = v\Delta n(r_n - r_0) - (n - \Delta n)(u - u_n) \qquad [8]$$

Substituting equation 8 in equation 3,

$$\begin{aligned} -n(u_0 - u) = u_n\Delta n + v\Delta n(r_n - r_0) - (n - \Delta n)(u - u_n) \\ -g(v - v_0) - (Z - z) \end{aligned} \qquad [9]$$

whence,

$$n = \frac{\Delta n[u + (r_n - r_0)v] - g(v - v_0) - (Z - z)}{(u - u_0)} \qquad [10]$$

If m is the ratio between the volume of the reservoir originally occupied by free gas and that occupied by oil,

$$m = \frac{gv_0}{nu_0} \qquad [11]$$

Substituting equation 11 in equation 10,

$$n = \frac{\Delta n[u + (r_n - r_0)v] - (Z - z)}{(u - u_0) + \dfrac{mu_0(v - v_0)}{v_0}} \qquad [12]$$

Equation 12 is the general equilibrium expression for fields having an original free gas cap and water drive. Where there is no water intrusion and no water is produced,

$$n = \frac{\Delta n[u + (r_n - r_0)v]}{(u - u_0) + \dfrac{mu_0(v - v_0)}{v_0}} \qquad [13]$$

Where there is no original free gas cap,

$$n = \frac{\Delta n[u + (r_n - r_0)v] - (Z - z)}{(u - u_0)} \qquad [14]$$

Where there is neither water drive nor an original free gas cap,

$$n = \frac{\Delta n[u + (r_n - r_0)v]}{(u - u_0)} \qquad [15]$$

There are three unknowns in equation 12; namely, the original quantity of oil in the reservoir, the original gas, and the quantity of water that may have encroached into the reservoir, attending the production of oil and gas. These unknowns are related to the quantities of oil, gas and water produced as well as the specific volumes of the oil and gas remaining in the reservoir. As stated before, the specific volumes are in turn functions of reservoir pressure. Equations 13, 14 and 15 hold for the specific cases where either water drive or an original free gas cap, or both, are absent. In the first two of these, the number of unknowns is reduced

to two, while in the last only one unknown, the original quantity of oil, appears.

Utility and Limitations of Equations

These formulas have certain advantages over that proposed by Coleman, Wilde and Moore, who made use of the laws for perfect gases and perfect solutions in their derivation. Here, such an assumption is not made; instead, the relations between pressure and volume determined in the laboratory on samples of the oil and gas are used in the application of the equations. Thus, the equations are applicable to the study of high-pressure reservoirs, whereas one that assumed the laws for ideal gases and solutions is very likely to be seriously in error. Most of the terms used in the expressions may be read directly from curves prepared from the laboratory data; therefore the calculations involved are simplified.

Except in so far as the specific volumes of the oil and gas in a reservoir are dependent upon the manner of liberation of the gas from solution in the oil, upon reduction of pressure, the equations are exact for a reservoir in which complete equilibrium between all phases is at all times established. Unfortunately, equilibrium is never attained. The deviations from equilibrium are such that reservoirs behave as though they contain considerably smaller quantities of oil and gas than they actually do contain. There are believed to be two conditions that make for this behavior. First and probably most important, it appears that much of the oil and gas is contained in relatively impermeable portions of the reservoirs wherein the pressures are not lowered to the same extent as in the more permeable sections that are first to furnish oil and gas for production. Thus, the oil and gas confined in the "tight" or relatively impermeable parts of the reservoirs do not have opportunity to expand and contribute toward filling the space vacated by oil and gas produced to the same extent as the oil and gas in the more permeable strata. A second possible condition that also may play some part in causing reservoirs to behave as though they contain less oil and gas than they actually do is the tendency for the oil remaining to fail to liberate its dissolved gas as pressure upon it is lowered, and thus for it to become supersaturated. It is clear that oil in such condition would fail to do its full part in expanding to fill voided space. Both of these conditions bring about the result that the reservoir pressures measured during the course of production are lower than those that would prevail if the decline in pressure were uniform and complete equilibrium established on the entire quantity of oil and gas in the reservoirs. For these reasons, the oil and gas content of a reservoir, as calculated by either of the equilibrium expressions 12, 13, 14 or 15, is always less than the true content. Despite the discrepancy, however, it is believed that the calculated quantity of oil has significance. It is

probably that part of the total quantity of oil that is contained in the interconnected and permeable portions of a reservoir, and, which actively contributes to the maintenance of the reservoir pressure. This introduces the concept of "active oil." Aside from its interpretation as the portion of the oil contained in the permeable parts of a reservoir, the "active oil" also has possible applications to the study of the performance of oil and gas reservoirs, as follows:

1. Determination of the effectiveness of any natural water drive that may be acting upon a reservoir.
2. To calculate the approximate pressure changes to be expected under various rates of flow in a field under water drive.
3. Evaluation of the benefits to be derived from gas return operations.
4. Estimation of the reservoir energy changes that occur during the course of production.

The use of the "active oil" in connection with the latter problem will be discussed in a part of the paper to follow.

General Application

The exact details of the manner in which the equations 12, 13, 14 or 15 may be employed to best advantage can be worked out only from a consideration of the data available in the particular case. No specific rules can be laid down. Where an original free gas cap is encountered, it is necessary to make some estimate, from geologic data, of the original size of the gas cap. This quantity is usually best expressed in the equations as a ratio between the portion of the original volume of the reservoir filled with free gas and that portion filled with oil.

Although ordinarily it is best to have the original reservoir conditions as a starting point for the application of the equations, it is not absolutely necessary. When little is known regarding actual original reservoir pressures, etc., any convenient subsequent time in the operations may be used; provided, of course, that all production and reservoir-pressure data employed in the computations are referred to the time chosen as a starting point.

The effect of any water drive that may be active is evaluated in the following manner: In many cases, it may be assumed that the rate at which water enters a field is proportional to the pressure gradient that exists between the water-bearing strata and the oil and gas reservoir. For practical purposes, the value of this gradient would be the difference between the value of the original reservoir pressure and any subsequent value, or $(p_0 - p)$. Thus, the rate of water encroachment would be expressed:

$$\frac{dZ}{d\theta} = k(p_0 - p) \tag{16}$$

whence:

$$dZ = k(p_0 - p)d\theta$$

and

$$Z = k\int_0^\theta (p_0 - p)d\theta \qquad [17]$$

To evaluate k, it is assumed that over any reasonably long period of time, during which the reservoir pressures and the production rate may have remained constant, the volume of water encroaching into the oil and gas reservoir is equal to the volumetric withdrawal, that is, the volume of oil, gas, and water withdrawn, all under reservoir conditions of pressure and temperature. Thus, from equation 16:

$$k = \frac{dZ}{(p_0 - p)d\theta}$$

and from equation 12:

$$\frac{dZ}{d\theta} = [u + (r_n - r_0)v]\frac{d(\Delta n)}{d\theta} + \frac{dz}{d\theta}$$

Combining these expressions:

$$k = \frac{[u + (r_n - r_0)v]\frac{d(\Delta n)}{d\theta} + \frac{dz}{d\theta}}{(p_0 - p)} \qquad [18]$$

under the conditions that $\frac{d(\Delta n)}{d\theta}$, $\frac{dz}{d\theta}$ and $(p_0 - p)$ are constant. In applying equation 18 to evaluate k from the production data over some particular period of time, it must be kept in mind that the value of r_n, the net gas-oil ratio produced, to use, is that observed for the particular period and not the average from the beginning. Having determined the constant k, the total influx of water over the entire period of production can be calculated, using equation 17.

It is of interest to know what the reservoir pressure would have been in a field under active water drive had the water drive been absent. For determining this, the following procedure may be employed: The reservoir volume filled with oil and gas at any time is given by either of the expressions,

$$\text{Reservoir volume} = nu_0(1 + m) - (Z - z)$$

$$\text{Reservoir volume} = (n - \Delta n)u + \left[\frac{nmu_0}{v_0} - \Delta n(r_n - r_0)\right]v$$

Equating:

$$nu_0(1 + m) - (Z - z) = (n - \Delta n)u + \left[\frac{nmu_0}{v_0} - \Delta n(r_n - r_0)\right]v \qquad [19]$$

Had there been no water drive, $(Z - z)$ would be zero, and the terms

u and v would have had values u' and v', corresponding to the pressure p', that would have prevailed in the absence of water drive. Therefore,

$$nu_0(1 + m) = (n - \Delta n)u' + \left[\frac{nmu_0}{v_0} - \Delta n(r_n - r_0)\right]v' \qquad [20]$$

Then, subtracting equation 20 from equation 19 and rearranging:

$$u' - u = \frac{(Z - z) - \left[\frac{nmu_0}{v_0} - \Delta n(r_n - r_0)\right](v' - v)}{n - \Delta n} \qquad [21]$$

Values of p' may be assumed, the corresponding values of u' and v' substituted in equation 21, and, by trial and error, the correct value of p' determined.

A specific example illustrating the application of the equations developed in the foregoing will be presented after consideration has been given to the energy changes that occur during the course of production.

Reservoir Energy

Reservoir energy may be defined as the energy available to produce oil. There are three sources of reservoir energy:

1. The expansive energy of the oil and the gas with which it is associated, both dissolved and free.
2. The energy supplied by water drive.
3. The energy of gravity, which usually is small and therefore may be neglected in most cases.

In producing oil, all of the expansive energy associated with all of the oil and gas produced is consumed. In addition, a part of the energy of the remaining oil and gas is also used, the amount depending upon the reduction in the reservoir pressure that accompanies the production. Water-drive or gas-return operations, by maintaining the reservoir pressure, conserve the energy of the oil and gas remaining in the reservoir.

To develop the expressions for calculating the energy changes that attend production, the following assumptions and conditions have been set out:

1. Oil and gas are considered to have been produced when they are brought to one atmosphere absolute pressure at the temperature of the reservoir.
2. The process of production is considered to be isothermal.
3. The fluids in reservoirs originally are considered to be free gas, if any is present initially, and oil with its dissolved gas. The oil with its dissolved gas is assumed to behave as a homogeneous fluid. The pressure-volume relations of both the original free gas and the oil with its original complement of dissolved gas are assumed to be independent of the quantities of each that remain in the reservoir.

4. Realizing that complete equilibrium is not attained within oil and gas reservoirs, the "active oil," calculated as outlined in the foregoing, is used as a basis for calculation of the energy changes. The probable

FIG. 1.—IMAGINARY THERMODYNAMIC ENGINE IN WHICH NET CHANGE IN ENERGY IS EQUIVALENT TO THAT IN OIL AND GAS RESERVOIR.

limitations involved in using the "active oil" in this manner will be discussed later.

In analyzing the reservoir energy change occurring on account of production, it is convenient to set up an imaginary thermodynamic engine, in which the net change in energy is equivalent to that brought

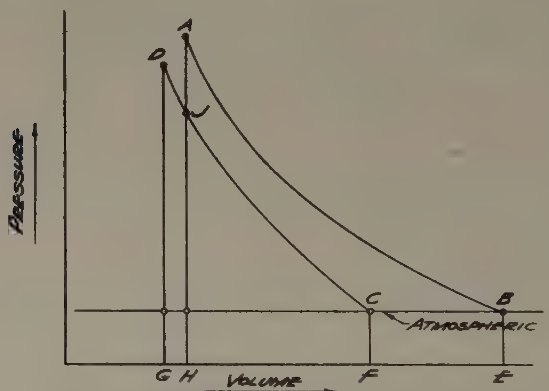

FIG. 2.—PRESSURE-VOLUME DIAGRAM.

about in the reservoir. Such an engine is illustrated in Fig. 1 and the process involved is as follows:

1. The fluids in the reservoir are allowed to expand isothermally to one atmosphere absolute pressure, the piston moving from position 1 to position 2. The curve of isothermal expansion is represented as the line *AB* on the pressure-volume diagram in Fig. 2. The work performed by the fluids is,

$$\int_B^A pdv, \text{ or the area } ABEH, \text{ under the line } AB.$$

2. The fluids to be produced are discharged from the engine at atmospheric pressure, the piston moving from position 2 to position 3. The volumes of the fluids change by the amount that is produced, but the pressure remains constant at atmospheric. This operation is indicated on the *p-v* diagram as the horizontal line *BC*, and the work done on the fluids is $p_a\Delta v$, or the rectangular area *BCFE*.

3. The fluids remaining in the reservoir must be recompressed to the new reservoir conditions; that is, the pressure and volume of the reservoir after the production has been obtained, the piston moving from position 3 to position 4. The final volume of the reservoir is less than the original volume by the net amount of water that has encroached into the reservoir. If there is no water drive, the final and original volumes are identical. The isothermal compression curve is represented by the line CD in the p-v diagram, and the work done on the fluids by the area $CDGF$.

The net energy change is the difference between the work performed by the fluids and the work later done on, or restored to, the remaining fluids. This is seen to be the area $ABCJ$ less the area $DJHG$, the latter being the energy contributed by any water drive that may be present. Thus, the change or consumption of reservoir energy is given by the expression

$$\Delta E = ABEH - BCFE - CDGF \tag{22}$$

The quantities above may be expressed as follows:

$$ABEH = n\int_{p_a}^{p_0} pdu + g\int_{p_a}^{p_0} pdv \tag{23}$$

$$BCFE = p_a[\Delta n u_a + \Delta n(r_n - r_0)v_a] \tag{24}$$

The energy remaining in the reservoir,

$$CDGF = (n - \Delta n)\int_{p_a}^{p} pdu + [g - \Delta n(r_n - r_0)]\int_{p_a}^{p} pdv \tag{25}$$

Then,

$$\Delta E = n\int_{p}^{p_0} pdu + g\int_{p}^{p_0} pdv + \Delta n\left[\int_{p_a}^{p} pdu + (r_n - r_0)\int_{p_a}^{p} pdv\right] - p_a\Delta n[u_a + (r_n - r_0)v_a] \tag{26}$$

If the energy consumption is to be expressed in units of energy per unit of oil produced,

$$\frac{\Delta E}{\Delta n} = \frac{n\int_{p}^{p_0} pdu + g\int_{p}^{p_0} pdv}{\Delta n} + \int_{p_a}^{p} pdu + (r_n - r_0)\int_{p_a}^{p} pdv - p_a[u_a + (r_n - r_0)v_a] \tag{27}$$

where

$$g = \frac{nmu_0}{v_0}$$

To calculate the extent to which any water drive that may be present contributes to the energy of the reservoir, the following equation applies:

$$\Delta E_w = (n - \Delta n)\int_{p'}^{p} pdu + \left[\frac{nmu_0}{v_0} - \Delta n(r_n - r_0)\right]\int_{p'}^{p} pdv \tag{28}$$

which is closely approximated by the expression

$$\Delta E_w = (Z - z)\frac{(p + p')}{2}$$

In equation 28, p' is the reservoir pressure that would have prevailed in the absence of the water drive.

Under ideal operation, without considering gas return, the oil would be produced with only its dissolved gas and at such a rate that water drive would maintain the reservoir pressure at its original value. Under this operation, the energy consumption would be limited to that associated with the oil, and its dissolved gas, produced. Thus:

$$\Delta E_m = \Delta n\left[\int_{p_a}^{p_0} p\,du - p_a u_a - p_0 u_0\right] \qquad [29]$$

It is observed that the following information must be known before the energy relationships expressed by equations 23 through 28 can be calculated:

1. Original store of oil and gas.
2. Data on oil and gas production.
3. Reservoir pressure behavior.
4. Data on the pressure-volume properties of the oil and gas, obtained through laboratory examination of samples.

For the original oil content of the reservoir, the "active oil" as determined from the applicable one of the equilibrium equations 12 to 15 is used in the energy expressions. As explained before, the calculated quantity of "active oil" is always less than the true total quantity of oil in the reservoir because the observed reservoir pressure decline is always greater than would have occurred if complete equilibrium were at all times established. By using the "active oil," or apparent quantity of oil contained in the reservoir, together with the observed decline in reservoir pressure, compensating errors are introduced. The quantity of fluids that are considered to have expanded is too small, but the pressure range over which the expansion occurs is too large by about the same order of magnitude. It is probable, therefore, that the use of the "active oil" and observed pressure decline leads to a fairly good approximation of the reservoir energy consumed.

Example of Application

By way of illustrating the use of the equations developed for calculating the "active oil" and the energy consumption, the Conroe field, Montgomery County, Texas, has been chosen as an example upon which the calculations will be made. This field has a free gas cap and there is considerable evidence to indicate that it is under active water drive. The case is therefore the most complicated for the application.

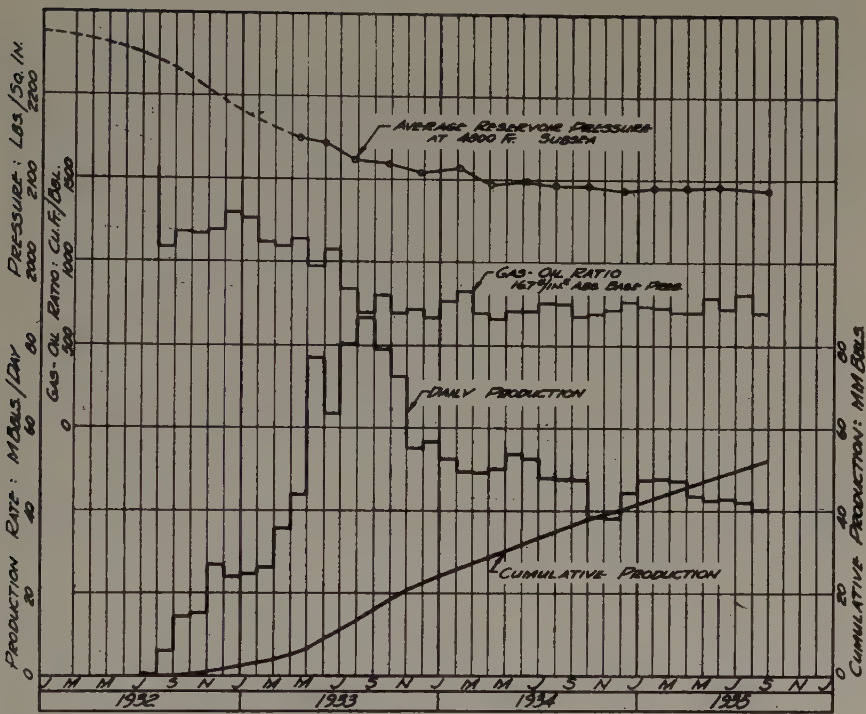

FIG. 3.—RESERVOIR PRESSURE AND PRODUCTION DATA, CONROE FIELD.

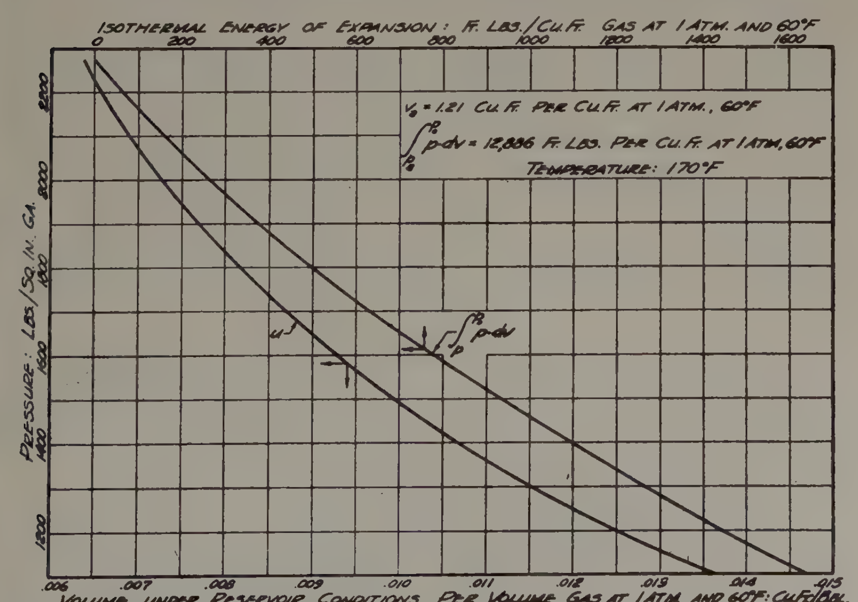

FIG. 4.—PRESSURE-VOLUME RELATIONS AND CALCULATED ISOTHERMAL ENERGY OF EXPANSION FOR CONROE OIL AND ORIGINAL COMPLEMENT OF DISSOLVED GAS.

The data on production and behavior of the average reservoir pressure are given in Fig. 3. The gas-oil ratios are referred to a 2-lb. pressure base. In Fig. 4 are presented the pressure-volume data on the oil with its original complement of dissolved gas, determined in the laboratory on subsurface samples of the oil from the Conroe field. Fig. 5 contains similar data on the gas from the free gas cap. In the calculations to follow, it is assumed that the production and reservoir-pressure data

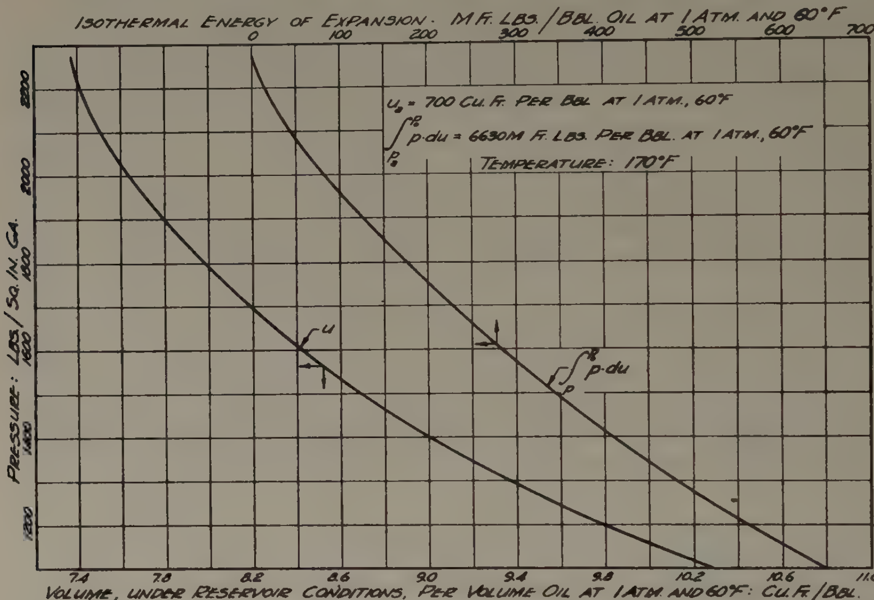

Fig. 5.—Pressure-volume relations and calculated isothermal energy of expansion for Conroe free gas.

apply only to the main Conroe sand and not to both the Conroe and upper Cockfield sands.

The field originally contained, in the Conroe sand, about 181,225 acre-feet of gas sand and 810,000 acre-feet of oil sand[4]. Therefore,

$$m = \frac{181{,}225}{810{,}000} = 0.224$$

During the period, Oct. 1, 1934, to Apr. 1, 1935, the production rate and reservoir pressure remained substantially constant. The data for this period are as follows:

Reservoir pressure, p; 2090 lb. per sq. in.
Pressure differential, $(p_0 - p)$; 185 lb. per sq. in.
Production rate, $d(\Delta n)/d\theta$; 44,100 bbl. per day

[4] E. O. Buck: Engineering Report on the Conroe Field, to Conroe Operators Association, Nov. 1, 1934.

Average volumetric displacement per barrel oil produced,*

$$u + (r_n - r_0)v;\ 9.09 \text{ cu. ft. per bbl.}$$

Average volumetric displacement,

$$\frac{dZ}{d\theta};\ 401{,}000 \text{ cu. ft. per day}$$

Rate of water encroachment, 401,000 cu. ft. per day

$$k = \frac{1}{(p_0 - p)} \cdot \frac{dZ}{d\theta};\ 2170 \text{ cu. ft. per day per lb. per sq. in.}$$

In Fig. 6, the curve of pressure drop against time is plotted, from which the expression,

$$\int_0^\theta (p_0 - p)\, d\theta$$

is obtained graphically. From this, Z is calculated from equation 17.

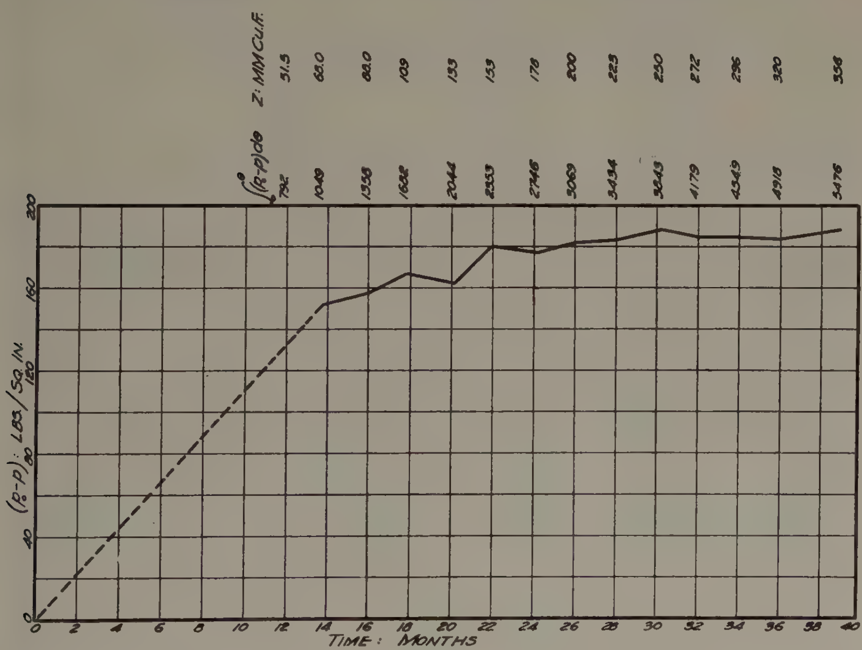

FIG. 6.—CALCULATION OF QUANTITY OF WATER THAT HAS ENCROACHED INTO CONROE FIELD.

A summary of the calculations involved in determining the original quantity of "active oil" in the reservoir by equation 12 is given in Table 1. "Active oil" is plotted against production in Fig. 7, wherein it is noted that the quantity has ranged between 550 and 600 million barrels for some time. Up to Sept. 1, 1935, between 8 and 9 per cent of the original

* Water production small and was neglected.

"active oil" had been produced. It is pointed out that the Conroe field has a slow rate of pressure decline, which may be due to one of two causes: (1) a very high content of "active oil," or (2) a lower "active oil" content coupled with a powerful water drive. To be conservative, the highest rate of water intrusion compatible with the data was used, which, in turn, makes the figures for "active oil" minimum values.

TABLE 1.—*Active Oil and Energy Calculations, Conroe Sand*

$u_i = 1.31 \times 5.62 = 7.37$ cu. ft./bbl., s.c.
$v_i = .00637$ cu. ft./cu. ft., s.c.
$u_w = 700$ cu. ft./bbl., s.c.
$v_w = 1.21$ cu. ft./cu. ft., s.c.
$\int_{p_a}^{p_i} p\,du = 6.63 \times 10^6$ ft.-lbs./bbl., s.c.
$\int_{p_a}^{p_i} p\,dv = 12{,}886$ ft.-lbs./cu. ft., s.c.
$m = \frac{181{,}265 \text{ Ac.-ft.}}{810{,}000 \text{ Ac.-ft.}} = 0.224$
$\frac{m u_i}{v_i} = 259$ cu. ft., s.c./bbl., s.c.

Quantity	Units	6-1-33	7-26-33	9-27-33	11-26-33	2-5-34	4-2-34	6-6-34	8-1-34	10-1-34	12-4-34	2-1-35	4-1-35	6-1-35
Δn	MM bbls., s.c.	9.070	10.84	18.24	22.34	26.08	28.65	32.03	34.83	37.71	40.18	42.90	45.65	48.24
$(\Delta n) r_n$	MM cu. ft., s.c.	14800	19100	23300	26400	29500	31900	34400	36700	38900	41200	43500	45800	48100
r_n	cu. ft., s.c./bbl., s.c.	1630	1760	1280	1180	1130	1110	1070	1050	1030	1025	1015	1005	995
$r_n - r_i$	cu. ft., s.c./bbl., s.c.	1030	1160	680	580	530	510	470	450	430	425	415	405	395
p	lbs./sq. in., ga.	2143	2123	2118	2108	2113	2095	2098	2093	2092	2087	2090	2090	2091
v	cu. ft./cu. ft., s.c.	.00676	.00682	.00684	.00687	.00686	.00691	.00690	.00692	.00693	.00694	.00693	.00693	.00693
$(r_n - r_i)v$	cu. ft./bbl., s.c.	6.95	7.90	4.65	3.98	3.64	3.53	3.24	3.12	2.98	2.95	2.87	2.81	2.74
u	cu. ft./bbl., s.c.	7.46	7.49	7.50	7.51	7.50	7.52	7.51	7.52	7.52	7.53	7.52	7.52	7.52
$u + (r_n - r_i)v$	cu. ft./bbl., s.c.	14.41	15.39	12.15	11.49	11.14	11.05	10.75	10.64	10.50	10.48	10.39	10.33	10.26
$v - v_i$	cu. ft./cu. ft., s.c.	.00039	.00045	.00047	.00050	.00051	.00054	.00053	.00055	.00056	.00057	.00056	.0005[illegible]	.00056
$\left[\frac{m u_i}{v_i}(v - v_i)\right]$	cu. ft./bbl., s.c.	.101	.116	.121	.129	.132	.140	.137	.142	.145	.147	.145	.145	.145
$u - u_i$	cu. ft./bbl., s.c.	.09	.12	.13	.14	.13	.15	.14	.15	.15	.16	.15	.15	.15
$(u - u_i) + \frac{m u_i}{v_i}(v - v_i)$	cu. ft./bbl., s.c.	.191	.236	.251	.269	.262	.290	.277	.292	.295	.307	.295	.295	.295
$\Delta n[u + (r_n - r_i)v]$	MM cu. ft.	131	167	222	256	291	317	345	372	396	422	446	472	495
$Z - z$	MM cu. ft.	51.5	68.0	88.0	109	133	153	178	200	223	250	272	296	320
$\Delta n[u + (r_n - r_i)v] - (Z - z)$	MM cu. ft.	79.2	99.0	134	147	158	164	167	173	174	172	174	176	175
$n = \frac{\Delta n[u + (r_n - r_i)v] - (Z - z)}{(u - u_i) + \frac{m u_i}{v_i}(v - v_i)}$	MM bbls., s.c.	415	420	534	548	603	566	602	591	586	560	590	596	594
$\int_p^{p_i} p\,dv$	ft.-lbs./cu. ft., s.c.	115	135	138	148	144	162	158	165	166	168	166	166	166
$\frac{m u_i}{v_i} \int_p^{p_i} p\,dv$	MM ft.-lbs./bbl., s.c.	.0298	.0350	.0358	.0384	.0373	.0420	.0410	.0428	.0430	.0436	.0430	.0430	.0430
$\int_p^{p_i} p\,du$	MM ft.-lbs./bbl., s.c.	.031	.038	.039	.043	.041	.047	.046	.048	.048	.050	.049	.049	.049
$\int_p^{p_i} p\,du + \frac{m u_i}{v_i}\int_p^{p_i} p\,dv$	MM ft.-lbs./bbl., s.c.	.0608	.0730	.0748	.0814	.0783	.0890	.0870	.0908	.0910	.0936	.0920	.0920	.0920
$n\left(\int_p^{p_i} p\,du + \frac{m u_i}{v_i}\int_p^{p_i} p\,dv\right)$	MMMM ft.-lbs. (A)	25.2	30.6	39.8	44.6	47.1	50.4	52.4	54.6	53.4	52.4	54.2	54.8	54.6
$\int_{p_a}^{p} p\,dv$	ft.-lbs./cu. ft., s.c.	12771	12751	12748	12738	12742	12724	12728	12721	12720	12718	12720	12720	12720
$(r_n - r_i)\int_{p_a}^{p} p\,dv$	MM ft.-lbs./bbl., s.c.	13.2	14.8	8.67	7.38	6.75	6.49	5.98	5.73	5.48	5.41	5.28	5.16	5.03
$\int_{p_a}^{p} p\,du$	MM ft.-lbs./bbl., s.c.	6.60	6.59	6.59	6.59	6.59	6.58	6.58	6.58	6.58	6.58	6.58	6.58	6.58
$\int_{p_a}^{p} p\,du + (r_n - r_i)\int_{p_a}^{p} p\,dv$	MM ft.-lbs./bbl., s.c.	19.75	21.39	15.26	13.97	13.34	13.07	12.56	12.31	11.96	11.99	11.86	11.74	11.61
$\Delta n\left(\int_{p_a}^{p} p\,du + (r_n - r_i)\int_{p_a}^{p} p\,dv\right)$	MMMM ft.-lbs. (B)	179	232	278	312	348	374	402	429	451	482	509	536	563
$u_{wt} + (r_n - r_i)v_w$	cu. ft./bbl., s.c.	1950	2105	1525	1409	1342	1318	1270	1245	1221	1215	1204	1191	1179
$\Delta n(u_{wt} + (r_n - r_i)v_w)$	MMM cu. ft.	17.7	22.9	27.8	31.4	35.0	37.8	40.7	43.4	46.0	48.9	51.6	54.4	56.9
$144 p_a \Delta n(u_{wt} + (r_n - r_i)v_w)$	MMMM ft.-lbs. (C)	57.5	48.6	59.0	66.5	74.1	80.1	86.4	92.0	97.5	104	109	115	121
$\Delta E = (A + B - C)$	MMMM ft.-lbs.	167	214	259	290	321	344	368	391	407	431	454	476	497
$\frac{\Delta E}{\Delta n} = \frac{(A+B-C)}{\Delta n}$ (avg. from beginning)	MM ft.-lbs./bbl., s.c.	18.4	19.7	14.2	13.0	12.3	12.0	11.5	11.2	10.7	10.6	10.5	10.4	10.3
$\frac{d(\Delta E)}{d(\Delta n)}$ (current)	MM ft.-lbs./bbl., s.c.	18.	27	6.1	7.3	8.3	8.5	7.3	8.2	5.6	9.7	8.4	8.0	8.1
$n\frac{m u_i}{v_i}$	MMM cu. ft., s.c.	107	109	138	142	156	147	156	153	152	145	153	154	154
$\Delta n(r_n - r_i)$	MMM cu. ft., s.c.	9.30	12.6	12.4	13.0	13.8	14.6	15.7	15.7	16.2	17.1	17.8	18.5	19.1
$n\frac{m u_i}{v_i} - \Delta n(r_n - r_i)$	MMM cu. ft., s.c.	98.0	96.0	126	129	132	132	140	137	136	128	135	135	135
$n - \Delta n$	MM bbls., s.c.	406	409	516	526	577	537	570	556	548	520	547	550	546
p'	lbs./sq. in., ga.	2080	2040	2030	2010	2005	1975	1965	1945	1935	1900	1895	1880	1865
$\frac{p + p'}{2}$	lbs./sq. in., abs.	2126	2096	2089	2074	2074	2050	2046	2034	2028	2008	2007	2000	1993
$\frac{144(Z-z)(p+p')}{2}$	MMMM ft.-lbs.	15.8	20.5	26.5	32.6	39.7	45.2	52.6	58.5	65.1	72.4	78.6	85.4	91.9
$\frac{144(Z-z)(p+p')}{2\Delta n}$	MM ft.-lbs./bbl., s.c.	1.74	1.89	1.45	1.46	1.52	1.58	1.64	1.68	1.73	1.80	1.85	1.87	1.90
Energy from Water (Avg. from beginning)	%	9.50	9.60	10.2	11.2	12.4	13.2	14.2	15.0	16.2	17.0	17.4	18.0	18.4
$d\left[\frac{144(Z-z)(p+p')}{2}\right]/d(\Delta n)$	MM ft.-lbs./bbl., s.c.	1.74	2.70	0.80	1.50	1.90	2.00	2.20	2.10	2.30	3.00	2.28	2.47	2.50
Energy from Water (current)	%	9.50	10.2	13.1	20.0	22.9	23.5	30.2	25.6	41.0	30.9	22.2	30.9	30.9

In Fig. 8, the observed record of the average reservoir pressures is compared with the values, calculated from equation 21, that would have prevailed had there been no water drive on the field. The figure shows that the average reservoir pressure as of Sept. 1, 1935, would have been 1820 lb. per sq. in. instead of the value observed, 2087 lb. per sq. in. It is apparent that the water drive has been of considerable importance in maintaining the reservoir pressure.

A summary of the calculations involved in determining the energy changes that attended production is also given in Table 1. The calculated values of the "active oil" were used in these computations. The

total energy consumption, expressed in foot-pounds, is plotted against the production in Fig. 9. The consumption of energy, assuming the water

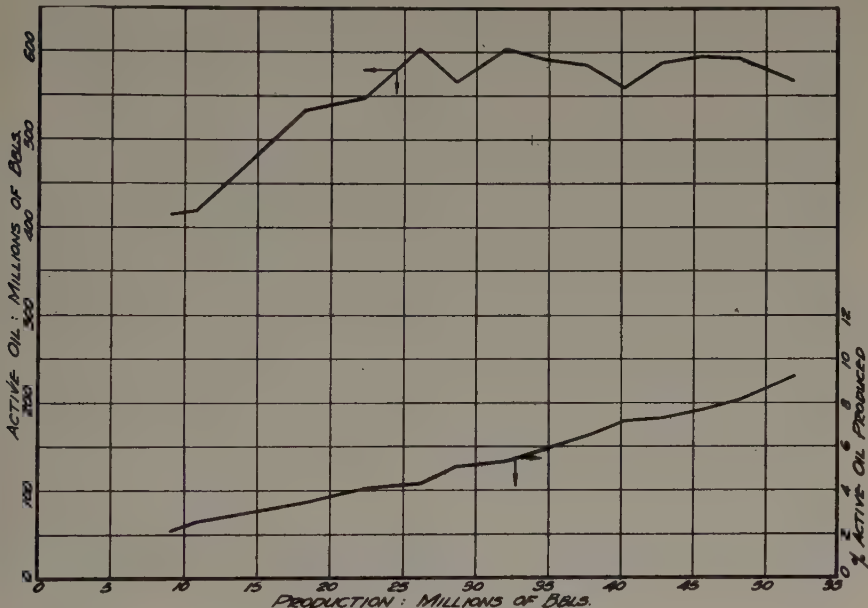

FIG. 7.—ACTIVE OIL, CONROE FIELD.

drive had been inactive, is also shown in Fig. 9. The energy consumed up to Sept. 1, 1935, would have been between 19 and 20 per cent higher had

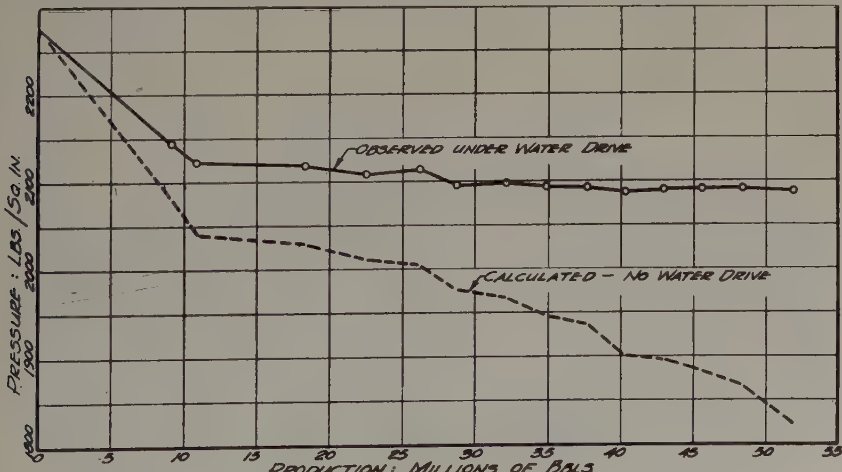

FIG. 8.—AVERAGE RESERVOIR PRESSURE DECLINE, CONROE FIELD.

the water drive been inactive. In Fig. 10, the reservoir energy consumption is expressed also as foot-pounds per barrel of oil produced. The

original energy content of the reservoir, including both the energy associated with the oil and its original complement of dissolved gas and

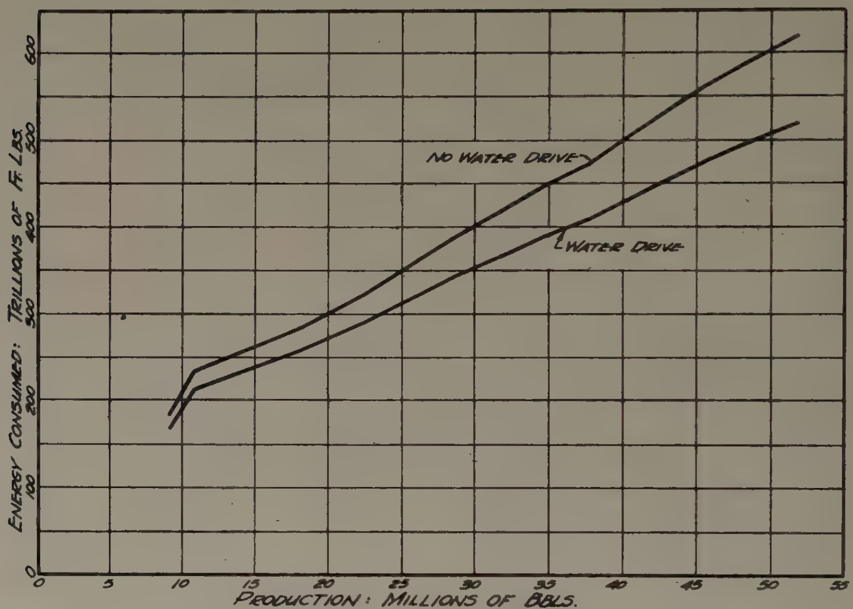

Fig. 9.—Total energy consumption, Conroe field.

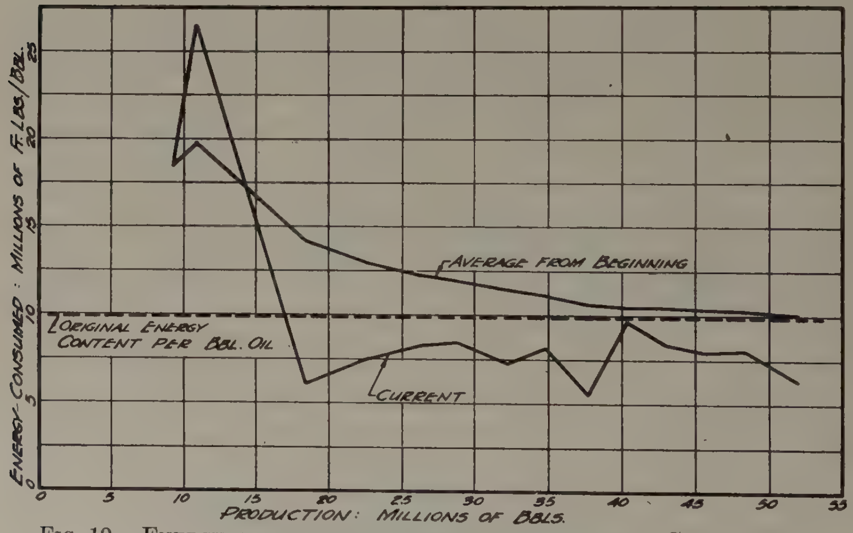

Fig. 10.—Energy consumed per barrel of oil produced, Conroe field.

the original free gas was 9.97 million foot-pounds per barrel of oil. In Fig. 10, it is seen that the energy consumed per barrel of oil produced was much higher during the early stages of production than the original

energy content, per barrel of oil. This was caused by the waste of excessive quantities of free gas during the early stages of production. Currently, the consumption of energy is even less than the original content per barrel because very few wells now produce with excessive gas-oil ratios. Most of the oil is produced with its dissolved gas only.

Conclusion

Where sufficient and proper data on production, reservoir-pressure behavior and the properties of the oil and gas are at hand, it is believed that the methods outlined herein permit the calculation of the approximate quantity of oil contained in the interconnected and permeable parts of a reservoir. Although the importance or significance of this quantity, termed "active oil," is not completely understood, it does appear to be of considerable interest. Its application at present seems to be in providing a means by which equilibrium expressions can be employed to calculate the effect of any natural water drive that may be present, to calculate the approximate pressure changes to be expected under various rates of flow in a water-drive field, to determine the benefits to be derived from gas-return operations, or to calculate the changes in reservoir energy that occur during the course of production. It is possible that the procedure may prove to be useful in estimating reserves, although its value along these lines cannot be determined until it has been applied in a number of cases so that comparison can be made with actual performance.

The application of production and subsurface pressure data in studies of the nature outlined herein points out their usefulness, and emphasizes the need for keeping even more adequate production and reservoir-pressure records than are now obtained.

DISCUSSION

(*M. Albertson presiding*)

W. K. Lewis,* Cambridge, Mass.—The factors determining the behavior in an oil reservoir are very complex, involving progressive segregation of oil from gas, simultaneous travel of the two phases through the structure, and the like. There seems no hope of solving the problem along purely theoretical lines. The solution must involve the use of empirical methods, but these should follow the best possible theoretical approach, as, for example, the development of formulas into which experimentally determined coefficients of performance may be introduced.

No true equilibrium can exist under conditions of production between free gas segregated at the top of the formation and the oil beneath it. However, while the gas actually liberated from the oil by reduction in pressure does not have the same composition as the segregated gas, where the pressures are high the difference is not great and probably can be neglected. Schilthuis' concept of active oil is a move in the right direction. Its use should give a clearer insight into what is actually occurring in the reservoir and, when adequately developed, a safer method of estimating ultimate performance.

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* Massachusetts Institute of Technology.

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D. L. Katz,* Bartlesville, Okla.—As reservoir pressure declines, is the mechanism by which gas escapes from solution in the oil that of equilibrium or differential vaporization?

R. J. Schilthuis.—The actual mechanism is probably some combination of both. However, the data on the saturation pressures and oil to gas ratios of subsurface samples taken from a few reservoirs after moderate decline in pressure had occurred seem to indicate that any gas that had escaped solution remained in contact with the oil from whence it came. Such samples were found to be substantially identical with others obtained very soon after development of the fields began and before any appreciable pressure decline had occurred. In view of this, it is believed that the tentative conclusion is justified that gas liberation in oil reservoirs conforms more closely with the equilibrium rather than the differential process over moderate pressure decline at least.

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* Phillips Petroleum Co.

Acre-foot Yields of Texas Gulf Coast Oil Fields

By Alexander Deussen,* Member, A.I.M.E.

(Houston Meeting, October 1935)

The figures listed in a table for Gulf Coast fields given by L. P. Teas[1] in 1934 are so greatly at variance with results that I have obtained from a serious study of this subject over a number of years, that I am disposed to challenge the correctness of Mr. Teas' figures as an accurate representation of acre-foot yields of Gulf Coast fields, and as regards at least two of the fields listed by Mr. Teas I desire to "put into the record" some figures that, according to my study, are more nearly in accord with what I conceive to be the actual facts.

Upon investigation I find that Mr. Teas' figures, inadvertently no doubt, are not what they purport to be. Apparently the figures were arrived at by considering as thickness of the producing formation the net thickness of producing rock corresponding "to the total of the net portions of the producing zones which actually yield oil into the drill hole"—and in following this method I am under the impression that Mr. Teas was acting under instructions of the Institute in the preparation of this paper, in order to get comparable figures from the several fields of the United States. Apparently the author interpreted these instructions to mean that in the absence of cored thicknesses of producing horizons the actual number of feet of screen set in the various producing zones was to be taken as the basis for arriving at the thickness of these zones and the "acre-foot" yields.

It is obvious that in many instances only 20 ft. of screen, or even 10 ft. of screen, might be set in a well, when there might be actually 100 ft. of oil sand present. In the early operations in the Gulf Coast it was usual to set much less screen than the amount of sand. It follows that the "acre-foot yields" so arrived at would be much greater than those found by using the full amount of sand.

In Mr. Teas' table, it was indicated that up to the end of 1933 "acre-foot" yields had been obtained in the several fields as listed in Table 1.

A casual inspection of these yields will show that certainly they do not properly reflect the amount of oil produced from an acre-foot of the

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* Consulting Geologist, Houston, Texas.

[1] L. P. Teas: Developments on the Gulf Coast of Texas during 1933. *Trans.* A.I.M.E. (1934) **107,** 309.

reservoir. They simply represent figures arbitrarily obtained by following this particular method of computation. A bed one foot thick and an acre in area contains 7758 bbl. of sand. Sufficient tests have been made of the porosity of various sands from Gulf Coast fields to show that the average porosity of representative sands is not over 25 to 30 per cent. If this entire pore space were filled with oil, it would contain only 1939 and 2327 bbl. of oil, respectively. To state, therefore, that the acre-foot yield of Spindletop is 7446 bbl. and of Orange 2599 bbl., is manifestly an exaggeration, as this would be more oil than could possibly be contained in the sand, and would assume 100 per cent recovery.

Table 1.—*Acre-foot Yields Listed by L. P. Teas*

Field	Acre-foot Yield, Bbl.
Barbers Hill	1,037
Big Creek	1,616
Goose Creek	1,778
Hull	1,654
North Dayton	1,188
Orange	2,599
Pierce Junction	1,956
South Liberty	1,537
Spindletop	7,446
West Columbia	1,159

It is, of course, a debatable question as to just what percentage of the oil originally in the reservoir has been recovered during the history of Gulf Coast development, but most authorities will agree, I believe, that it does not in general exceed 40 per cent. If this be the actual percentage of recovery the maximum amount of recoverable oil could be only 931 bbl. to the acre-foot, with 30 per cent porosity.

All of the available data indicate that only a small part of the oil originally contained in a reservoir is recovered by the usual production methods. The classic case of the Bradford sand of Pennsylvania is of course well known. Melcher's experiments on cored sections from apparently depleted areas of this field revealed that only 25 per cent of the oil originally in the reservoir had been recovered. It is estimated that 350,000,000 additional barrels will be recovered by flooding methods, although from the Bradford sands less than 250,000,000 bbl. had been produced during the previous 50-year history of this field[2].

In the Gulf Coast are numerous examples of wells that have cored through depleted sands and recovered cores highly saturated with oil; although such areas previously had produced large quantities of oil to the acre, now they are nonproducing. Humble Oil & Refining Company's No. 10 Welder, on the west side of the South Liberty dome, cored the depleted Heterostegina sand from 3615 to 3720 ft. and found it highly

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[2] American Petroleum Supply and Demand, 101. Amer. Petr. Inst. 1925.

saturated with oil, although repeated drill-stem tests failed to show any oil whatever. Wells now being drilled in the depleted area at Damon Mound are recovering highly saturated cores, but only strippers are being completed. Numerous similar instances, in areas formerly prolific, are known at Orange, Goose Creek, West Columbia, and elsewhere on the coast.

In 1930 I made a careful study of both the Goose Creek and Orange fields in a deliberate effort to discover just what these two blanket-type fields had produced per acre-foot in the past. Most of the well records were carefully examined. In this investigation, the amount of sand logged throughout the various producing zones was used to arrive at the approximate amount of oil-bearing formation. The results of this investigatoin showed that up to 1930 Goose Creek had produced 477 bbl. to the acre-foot and Orange had produced 767 bbl. to the acre-foot. I am of the opinion that these figures undoubtedly are a much closer approximation to the actual acre-foot yields of these two fields than the figures given in Mr. Teas' table (1778 and 2599 bbl.).

It is apparent that the screen method in computing the thickness of a reservoir cannot be used to determine accurately this thickness and that the only proper method is to add up the actual sand penetrated.

Chapter II. Production Engineering

Experiments on the Vertical Flow of Gas-liquid Mixtures in Glass Pipes

By J. E. Gosline*

(Houston Meeting, October, 1935)

In any theory of a hydrodynamic nature dealing with the vertical flow of gas-liquid mixtures in pipes, the two factors that present the greatest difficulty are the relative motion between the phases and the energy loss resulting from turbulence work. The former has generally been referred to in the literature as "slippage" and the latter as "friction." A third factor of importance is the nature of admixture between liquid and gas for both the relative motion between the phases as well as the turbulence work are functions of the type of mixture.

Although much work of a general nature has been performed on the vertical flow problem, there have been very few attempts made to study experimentally the factors involved in the phenomenon individually. Of these, perhaps the most notable is the work of Moore and Wilde[1] on slippage.

Some writers on the subject have assumed that over a wide range of operating conditions the controlling type of mixture is one in which gas bubbles of uniform size are distributed throughout the liquid, and that the data obtained from experiments on the motion of single bubbles through various liquids may be used in evaluating the slippage. Versluys[2] has further assumed another controlling type of mixture in which the liquid occurs as a dispersed phase within the gas and applies data on the fall of drops of water in air to calculating the relative velocity.

It was for the purpose of studying the applicability of data on single bubble motion to the slippage factor and to further observe the nature of mixtures that a research program was conducted at the University of California during 1932 and 1933. These experiments formed a basis for

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* Petroleum Engineer, Standard Oil Company of California, San Francisco, Calif.

[1] T. V. Moore and H. D. Wilde, Jr.: Experimental Measurement of Slippage in Flow Through Pipes. *Trans.* A.I.M.E. (1931) **92**, 296.

[2] J. Versluys: Some Principles Governing the Choice of Length and Diameter of Tubing in Wells. *Trans.* A.I.M.E. (1931) **92**, 279.

the author's Ph. D. thesis and certain portions of the work have been drawn upon in the preparation of this paper.

Experiments on Motion of Single Bubbles

The motion of single bubbles of small size rising through liquids has been extensively investigated, but the sizes have been below those usually encountered in vertical flow. It was necessary, therefore, in order to investigate the applicability of data on single-bubble motion to the

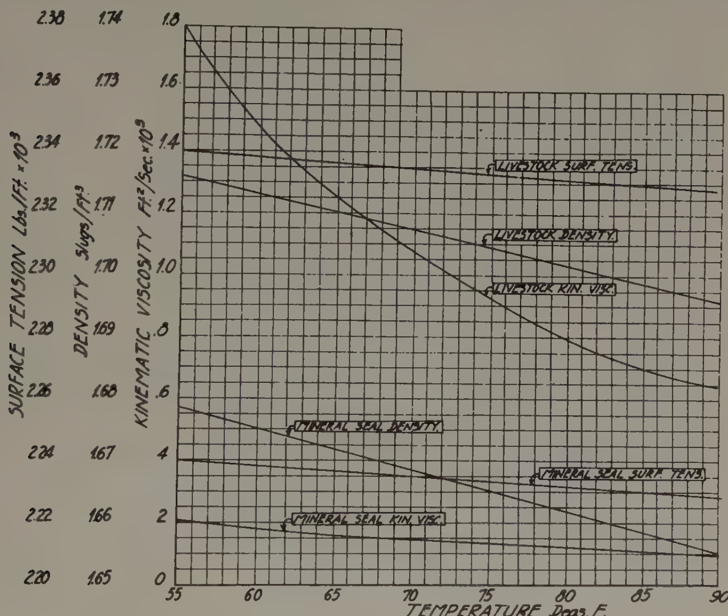

Fig. 1.—Physical properties of Mineral Seal and Livestock oils.

slippage factor to obtain complete information on the motion of the larger bubbles. The results of this part of the investigation were presented in a paper read before a meeting of the Society of Rheology at Pittsburgh, Pennsylvania, in December, 1933. To avoid undue repetition, only those portions of the bubble-motion study that have a direct bearing upon the material of this paper will be discussed.

Experiments were conducted in which the average velocity of rise of air bubbles through water and two colorless petroleum oils was measured. The pipes used were of glass and had internal diameters of 1.18, 2.24 and 6 in. The physical properties of petroleum oils were determined and appear in Fig. 1. The results of the velocity measurements appear in Figs. 2, 3 and 4, in which the radius of a sphere having a volume equivalent to that of the volume of the bubble is expressed as a function of the average velocity of rise. It is apparent from these curves that the size

of the bubble and the size of the tube have a material effect upon the average velocity. The effect of viscosity and surface tension were very

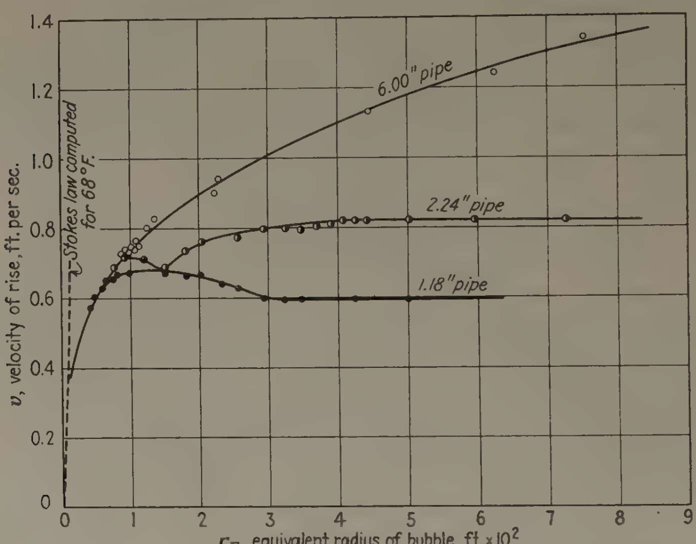

FIG. 2.—AIR BUBBLES IN WATER. TEMPERATURE RANGE OF WATER FROM 66° TO 71° F.

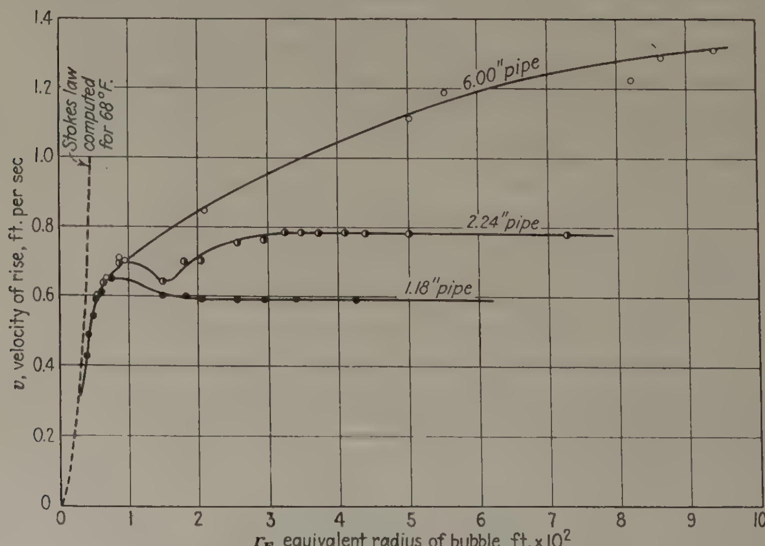

FIG. 3.—AIR BUBBLES IN MINERAL SEAL OIL. TEMPERATURE RANGE OF OIL FROM 65° TO 70° F.

minor for the range studied. It will not be necessary for the purpose of this paper to consider the anomalies in the shapes of the velocity curves.

Experiments on Nonflow Mixtures of Air and Liquids

The following ideal conditions may be postulated for the admixture of gas and liquid in the riser pipe of an air or gas-lift system:

1. The gas forms a dispersed phase of bubbles distributed throughout the liquid.

2. The liquid forms the dispersed phase as globules in contact with the gas stream.

3. The gas forms bullet-shaped pistons, which fill the pipe and which are alternated by slugs of liquid.

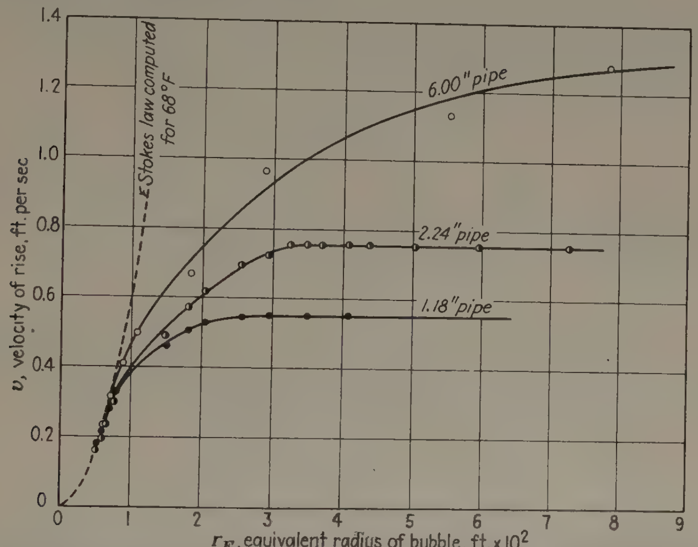

Fig. 4.—Air bubbles in Livestock oil. Temperature of oil from 66° to 71° F.

4. The liquid forms an annular ring in contact with the wall of the tube, up through which the gas flows.

Regardless of which condition is assumed, a knowledge of the relative motion between the two phases is essential to an analysis of the flow.

Most writers have assumed that the first condition listed above is the controlling regime. If that is true, the only method of even approximate determination of the slip-velocity factor, which does not depend upon additional experimental work, is the application of the type of data presented in the first section of this paper on single-bubble motion. If such data may be generally used in this manner, it is necessary that a condition of mixture exist over a wide range of operating conditions in which a fairly uniform size of bubbles is distributed in a homogeneous manner throughout the liquid.

In order to investigate the applicability of the single-bubble data to a mixture the average velocity of rise of air through a nonflow medium of

the three liquids used in the single-bubble experiments was determined. These data were then compared with values obtained from the single bubbles, due regard being given to the size of the bubbles in the mixtures. The following considerations were applied to the stationary mixtures.

At any section in the riser pipe of an air or gas-lift, regardless of whether the mixture is stationary or moving, the specific weight of the mixture at that section is

$$\gamma = \frac{A_L\gamma_L + A_G\gamma_G}{A} \qquad [1]$$

where A_L and A_G are the areas occupied by liquid and gas, respectively, γ_L and γ_G are their specific weights, and A is the area of the pipe. This expression may be rewritten as

$$\gamma = \frac{\left(A - \dfrac{W_G}{\gamma_G v_G}\right)\gamma_L + \dfrac{W_G}{v_G}}{A} \qquad [2]$$

where W_G is the weight per second of gas flowing, and v_G is the absolute velocity of the gas. If the gas obeys the perfect gas law

$$\gamma_G = \frac{P}{RT} \qquad [3]$$

where P is the absolute pressure, R the gas constant, and T the absolute temperature. Substitution of eq. 3 into eq. 2 gives

$$\gamma = \gamma_L + \frac{W_G}{Av_G}\left(1 - \frac{RT\gamma_L}{P}\right) \qquad [4]$$

Now, Hoefer[3] has shown that for stationary mixtures γ is a linear function of length, so that the mean specific weight of the mixture is

$$\gamma_M = \frac{\gamma_1 + \gamma_2}{2} \qquad [5]$$

where subscripts 1 and 2 refer to the bottom and top of the mixture, respectively. Using equation 4 for the specific mixtures weights,

$$\gamma_M = \frac{\gamma_L + \dfrac{W_G}{Av_{G_1}}\left(1 - \dfrac{RT_1\gamma_L}{P_1}\right) + \gamma_L + \dfrac{W_G}{Av_{G_2}}\left(1 - \dfrac{RT_2\gamma_L}{P_2}\right)}{2} \qquad [6]$$

Hoefer[4] also established that for stationary mixtures

$$v_{G_1} = v_{G_2}$$

[3] K. Hoefer: Untersuchungen uber Stromungsvorgange im Steigrohr eines Druckluftwasserhebers. *Ztsch.* ver. deut. ing. (1913) **42,** 987–988.

[4] K. Hoefer: Reference of footnote 3.

Calling this v_G, equation 6 may be expressed as

$$\gamma_M = \gamma_L + \frac{W_G}{Av_G} - \frac{W_G}{Av_G} \times \frac{R\gamma_L}{2}\left(\frac{T_1}{P_1} + \frac{T_2}{P_2}\right) \qquad [7]$$

If, for the case of a stationary or nonflow mixture,

H = original fluid level before injection of gas,
ΔH = rise of level due to gas injection,
γ_L = unit weight of liquid,
γ_{G_M} = mean unit weight of gas in pipe,
A = area of pipe,

then, the mean specific weight of the mixture in the pipe is

$$\gamma_M = \frac{A\Delta H\gamma_{G_M} + AH\gamma_L}{A(H + \Delta H)} \qquad [8]$$

For low pressures the term $A \cdot \Delta H \cdot \gamma_{G_M}$ may be neglected in comparison with $AH\gamma_L$, so that

$$\gamma_M \approx \frac{AH\gamma_L}{A(H + \Delta H)} \approx \frac{H\gamma_L}{H + \Delta H} \qquad [9]$$

Solving equation 7 for v_G and substituting the value of γ_M given by equation 9 and simplifying gives

$$v_G \approx \frac{H + \Delta H}{\gamma_L \Delta H}\left[\frac{W_G R\gamma_L}{2A}\left(\frac{T_1}{P_1} + \frac{T_2}{P_2}\right) - \frac{W_G}{A}\right] \qquad [10]$$

As has been noted previously, Hoefer[5] found that v_G was equal at the top and bottom of his stationary mixtures. He found also that v_G decreased slightly toward the center of the tube. For all practical purposes, however, it may be considered that the value of v_G given by equation 10 measures the mean velocity of the gas. In the stationary mixtures v_G is the slip velocity, since the liquid velocity is zero on the average.

In determining the slip velocities for stationary mixtures a 6-in. Pyrex vertical glass pipe column 26.56 ft. long was used. The air flow was measured by means of an orifice meter. The liquids employed were water and the two petroleum oils used for the single-bubble experiments. Several rates of air flow were used for each initial liquid level and three fluid levels for each liquid.

For all three liquids, the mixtures formed were extremely nonhomogeneous and highly turbulent. For high air rates light colored flashes could be observed passing up through the mixture with a high velocity. These were irregular masses of air flowing up the central portion of the pipe.

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[5] K. Hoefer: Reference of footnote 3.

The mean velocity of the air (the slip velocity) was calculated for all runs by means of equation 10. The results are shown in Fig. 5, in which the mean velocity is shown as a function of weight of air per second. It is to be noted that the physical characteristics of the liquid have little effect upon the velocity, the deviations of the points from the mean curve drawn being erratic. This is in agreement with the results of the single-bubble experiments in which the velocity of rise was largely independent of the characteristics of the liquid within the range studied. Fig. 5 shows that for the lowest rate of air flow the velocity was 1.53 ft. per second for water. For the single-bubble experiment the highest velocity measured with water in the same size of pipe was only 1.34 ft. per second,

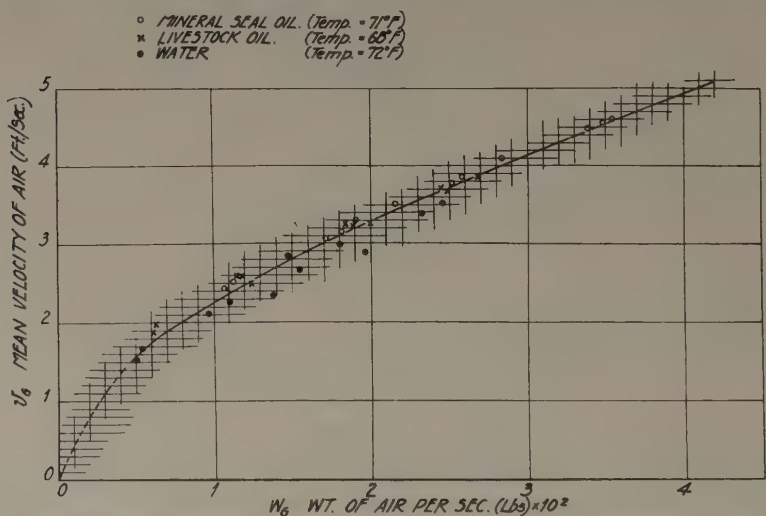

Fig. 5.—Mean velocity of air in stationary mixtures in 6-inch glass pipe.

and this was for a bubble that completely filled the 6-in. pipe. In order to correlate data even approximately, for the single-bubble experiments with the results shown in Fig. 5, it would be necessary that for the lowest rate of air flow the size of the bubbles in the mixture be such as to fill the pipe. Actually, all sizes of bubbles were observed in the mixture from those small enough to obey Stokes' law up to the large irregular air masses previously referred to. Moreover, the extreme turbulence of the mixture certainly causes impact and disorderly motion of the air to such an extent that, even if the mixture were composed of a uniform, observable size of bubble, the air would not move in accordance with the velocity predicted from single-bubble experiments.

Although the mixture experiments were confined to the non-flow case, and were carried out in only one size of pipe, it is believed that the results point to the inapplicability of single-bubble data to the slip velocity factor in an air or gas-lift.

Pumping Experiments

In order to observe visually the nature of admixture between liquid and gas phases under conditions of flow a small gas-lift was constructed of glass. The tubing or riser pipe was a column of 1.05 in. internal

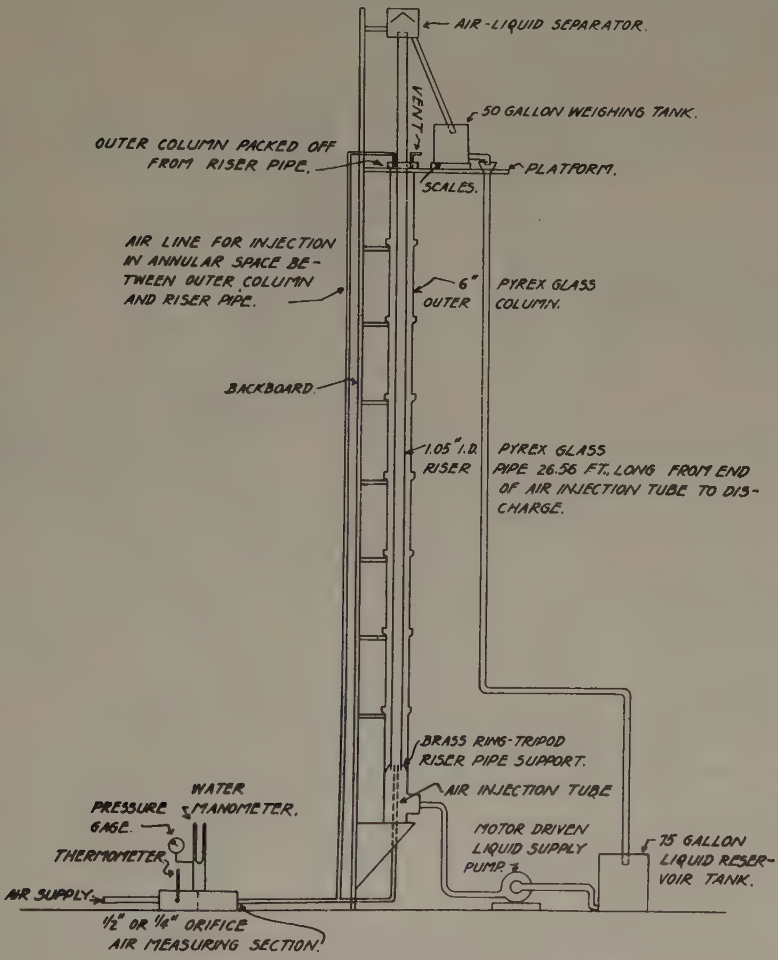

Fig. 6.—Apparatus used in pumping experiments.

diameter Pyrex pipe coupled in 3-ft. joints. The casing or outer pipe was built up of 6-in. Pyrex joints. A diagrammatic sketch of the apparatus is shown in Fig. 6. Air furnished by a compressor was used as a gas. The air flow was measured by means of an orifice meter and the liquid flow was measured gravimetrically. Air injection was either (1) by means of an air-injection tube into the riser pipe or (2) in the annular space between riser pipe and casing. Submergence in the first method

was observed directly as a fluid level and in the second was measured as a pressure equivalent to a fluid head by means of a pressure tube in the plane of the bottom of the riser pipe.

The liquids used were water and the same two colorless petroleum oils employed in the bubble experiments and stationary mixture studies. In all experiments the submergence was held constant for a series of runs and the air flow was varied.

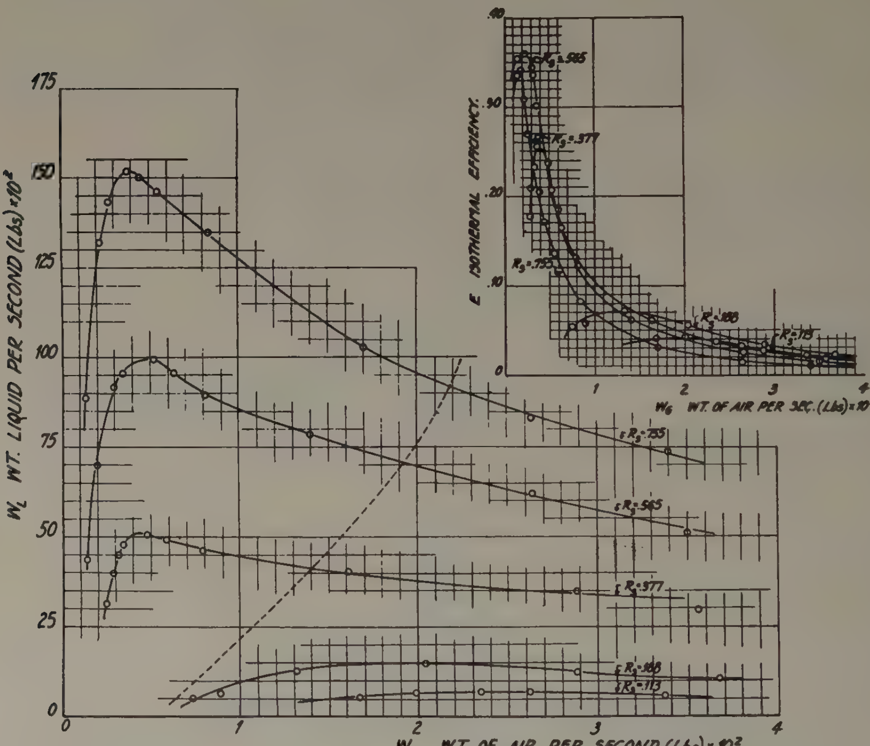

FIG. 7.—PUMPING EXPERIMENTS WITH WATER. AIR INJECTED WITH TUBE.

The first series of tests was with water, using annular space injection of air. These same runs were repeated using the tube method of air injection. The results from the two methods were identical, except that when the annular-space method was used with low air rates the pumping ceased suddenly, owing to back flow of the air out of the bottom of the riser and the subsequent sealing off of this air inlet area by the rise of the liquid surface. Since it was desired to obtain the complete operating characteristics—i.e., low air rates—and since there seemed to be no other difference in operation as between the two methods, the tube injection was used in all other experiments.

Figs. 7, 8 and 9 show the operating characteristics for the three liquids. On the large graph of each of these figures, liquid flow is shown as a function of air flow for five submergence ratios, where the submergence ratio is defined as

$$R_s = \frac{\text{Submergence}}{\text{Submergence} + \text{Lift}} \qquad [11]$$

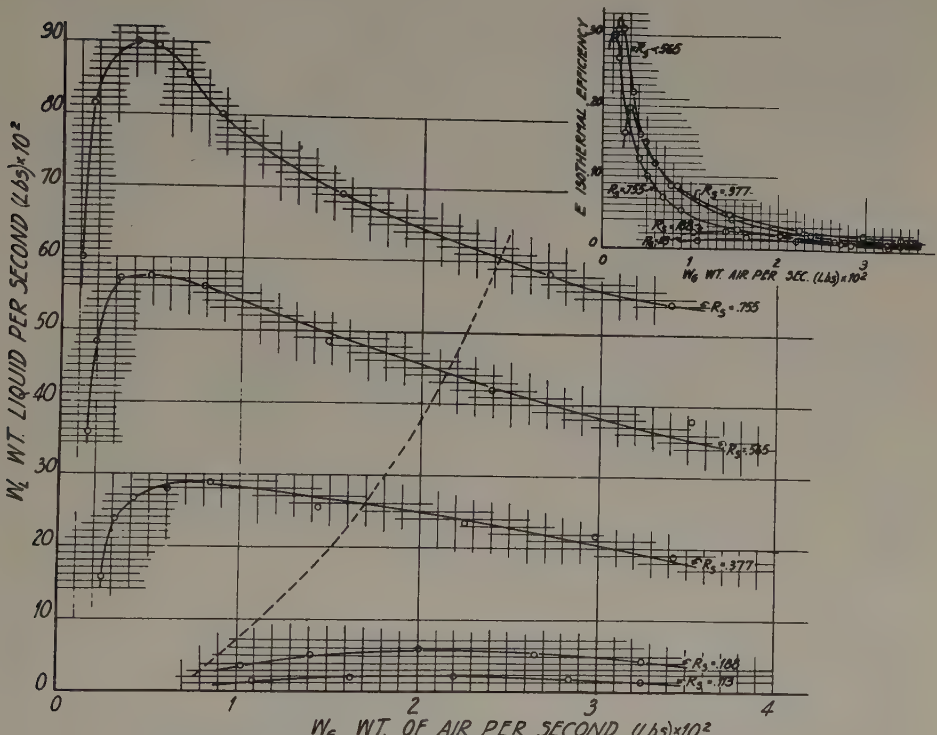

Fig. 8.—Pumping experiments with Mineral Seal oil. Air injected with tube.

On the small graphs of the figures appear isothermal efficiency as a function of air rate for the various values of R_s. The isothermal efficiency was computed by means of the conventional expression

$$E = \frac{W_L H_L}{W_G RT \log_e P/P_A} \qquad [12]$$

where W_L is weight of liquid per second, H_L is lift, W_G is the weight of air per second, P is the pressure at bottom of riser, and P_A is atmospheric pressure.

With regard to Figs. 7, 8 and 9, there is a progressive decrease of W_L for a given W_G and R_s as the viscosity of the liquid increases; i.e., water, mineral seal oil and livestock oil. In Fig. 10, this fact is more clearly

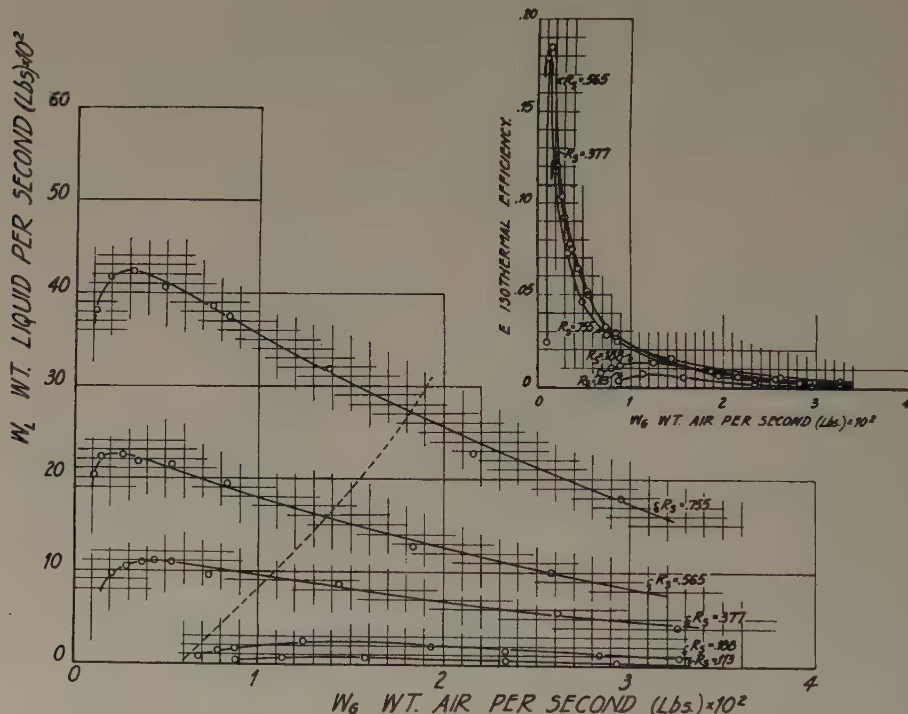

FIG. 9.—PUMPING EXPERIMENTS WITH LIVESTOCK OIL. AIR INJECTED WITH TUBE.

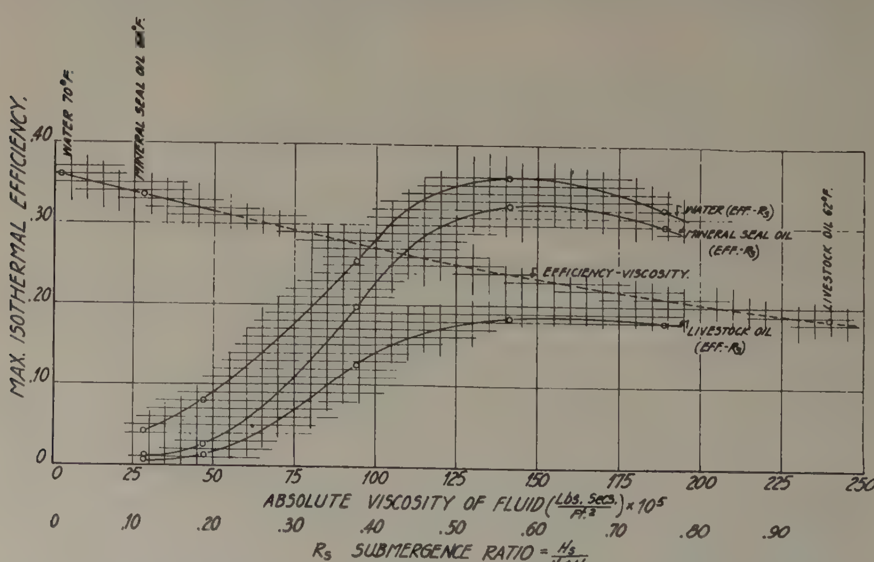

FIG. 10.—MAXIMUM EFFICIENCY, VISCOSITY AND SUBMERGENCE RATIO RELATIONS FOR PUMPING EXPERIMENTS.

shown in which the maximum isothermal efficiency for the three liquids has been represented as a function of the absolute viscosity of the liquids at the average experimental temperatures. On the same curve, the maximum efficiency is shown as a function of the submergence ratio for the three liquids. The value of

$$R_s = 0.57$$

for best efficiency for all liquids corresponds with practically all published data on air-water lifts.

In all of the experiments there was a very definite change in the behavior of the mixture in the riser pipe as the rate of air flow was increased. For all submergences corresponding to $R_s = 0.188$ low rates of air flow were accompanied by high turbulence and unsteadiness of flow. This general condition of nonuniformity seemed to predominate in the steep rising portion of the curves shown in Figs. 7, 8 and 9. Since the point of best operation occurs in this region, it follows that such conditions are conducive to highest efficiency. As the rate of air flow was increased, the unsteadiness decreased, and finally the flow became quite steady. This steady motion, however, was accompanied by a change in the nature of admixture of air and fluid. The fluid was present in the tube as an annular ring in contact with the tube wall and the air moved up through the central portion. Broken lines on the performance curves of Figs. 7, 8 and 9 indicate the approximate division as observed between the unsteady, turbulent type of flow and the annular ring condition. To the right of the broken line is the region of the annular ring and to the left the region of the unsteady mixture.

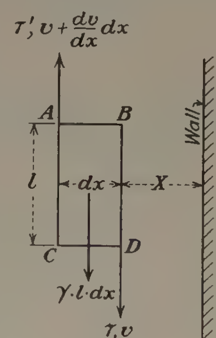

FIG. 11.

In connection with the annular ring type of admixture it seems logical to consider that the energy of the air stream is transmitted to the fluid by means of tractive forces at the interface. These forces are opposed by the internal resistance to motion of the liquid and by the weight of the liquid.

For the case in which the thickness of the liquid annulus is small in comparison to the radius of the pipe, the flow in the annulus may be treated as sheet flow with one free surface without inducing material error.

Considering a radial section of the annulus having unit width perpendicular to the plane of the section, the forces acting on an element of the fluid within the section are the shearing forces and the body force. If x be measured positively from the wall of the pipe toward the axis of the pipe, and if the length of the small element be l (Fig. 11), the shearing force on the surface BD is

$$\tau = -\mu \frac{dv}{dx} l \qquad [13]$$

where μ is the coefficient of viscosity of liquid. The shearing force on the surface AC is

$$\tau' = \mu\frac{d}{dx}\left(v + \frac{dv}{dx}dx\right)l \qquad [14]$$

The body force acting through the center of gravity of the element is $-\gamma l dx$ where γ is the unit weight of the liquid. For equilibrium of the element

$$-\mu\frac{dv}{dx}l + \mu\frac{dv}{dx}l + \mu\frac{d^2v}{dx^2}dxl - \gamma l dx = 0 \qquad [15]$$

or

$$\frac{d^2v}{dx^2} = \gamma \qquad [16]$$

Integration of equation 16 gives

$$v = \frac{1}{2}\frac{\gamma}{\mu}x^2 + C_1x + C_2 \qquad [17]$$

where C_1 and C_2 are constants to be determined from the boundary conditions.

Now, at $x = 0$ the fluid adheres to the wall and $v = 0$, therefore $C_2 = 0$. At $x = t$, where t is the thickness of the annulus, the fluid velocity is a maximum, so that

$$C_1 = \frac{v_{\max} - \frac{1}{2}\frac{\gamma}{\mu}t^2}{t} \qquad [18]$$

and equation 17 may be written as

$$v = \frac{1}{2}\frac{\gamma}{\mu}x^2 + \frac{v_{\max}x}{t} - \frac{1}{2}\frac{\gamma}{\mu}tx \qquad [19]$$

The mean velocity in the annulus may be obtained from equation 19 from

$$v_M = \frac{1}{t}\int_0^t v\,dx = \frac{1}{t}\int_0^t \frac{\gamma}{2\mu}x^2dx + \frac{1}{t}\int_0^t \frac{v_{\max}}{t}x\,dx - \frac{1}{t}\int_0^t \frac{\gamma}{2\mu}tx\,dx \qquad [20]$$

$$v_M = \frac{1}{2}v_{\max} - \frac{1}{12}\frac{\gamma}{\mu}t^2 \qquad [21]$$

Therefore, the maximum velocity is

$$v_{\max} = 2v_M + \frac{1}{6}\frac{\gamma}{\mu}t^2 \qquad [22]$$

The equation of the velocity distribution curve in the annulus is obtained by substituting the value of $v_{\max}$ from equation 22 into equation 19, which gives

$$v = \frac{1}{2}\frac{\gamma}{\mu}x^2 + \frac{2v_M x}{t} - \frac{1}{3}\frac{\gamma t x}{\mu} \qquad [23]$$

The slope of the velocity distribution curve at any point is

$$\frac{dv}{dx} = \frac{\gamma}{\mu}x + \frac{2v_M}{t} - \frac{1}{3}\frac{\gamma}{\mu}t \qquad [24]$$

The slope at the air-liquid interface is

$$\left(\frac{dv}{dx}\right)_{x=t} = \frac{\gamma}{\mu}t + \frac{2v_M}{t} - \frac{1}{3}\frac{\gamma}{\mu}t \qquad [25]$$
$$= \frac{2v_M}{t} + \frac{2}{3}\frac{\gamma t}{\mu}$$

The shearing force per unit area at the interface is then

$$\tau_{x=t} = \mu\left(\frac{dv}{dx}\right)_{x=t} = \frac{\mu 2v_M}{t} + \frac{2}{3}\gamma t \qquad [26]$$

This shearing force is equivalent to the tractive force of air per unit area of interface, and assuming that this varies as the square of the air velocity (turbulent air flow),

$$D = C_D\rho v_G^2 = \mu\frac{2v_M}{t} + \frac{2}{3}\gamma t \qquad [27]$$

where C_D is a coefficient of drag, ρ is the density of the air, and v_G is the velocity of the gas.

Solving equation 27 for C_D,

$$C_D = \frac{\mu 2v_M}{t\rho v_G^2} + \frac{2}{3}\frac{\gamma t}{\rho v_G^2} \qquad [28]$$

For all liquids and values of $R_s = 0.188$ in the pumping experiments, the annular ring type of admixture was found to maintain over the whole operating range. For these runs, therefore, Pitot tube measurements were made at the top of the riser pipe in order to measure the absolute velocity of the air "core." The diameter of the Pitot tube was 62⁄1000 in., and it was carefully polished to eliminate burrs or roughness. Measurements were made in the center of the pipe ¼ in. below the plane of the opening. The air velocities were sufficiently high to be in turbulent flow and the liquid velocities of such magnitude as to be in viscous flow. With these data it was possible to obtain the absolute air velocities, the absolute liquid velocities and the thickness of the annulus t. Equation 28 was then used to calculate the drag coefficient C_D. The results of such calculations for the various runs appear in Fig. 10. The coefficient of drag diminishes rapidly with the absolute velocity of the gas. Moreover, the drag appears to increase with viscosity of liquid.

Unfortunately, time did not permit investigation of the effect of diameter and nature of pipe upon the thickness of the annulus. Unquestionably these are of major importance. Probably there is also a variation of thickness of annulus along the pipe, controlled to a large extent by pressure variation brought about by friction.

Certainly a range of conditions occurs in many gas-lifts, which is compatible with the formation and existence of an annular ring type of admixture in the flow string. Small tubing, high gas-oil ratios and low submergences would be factors conducive to such a condition.

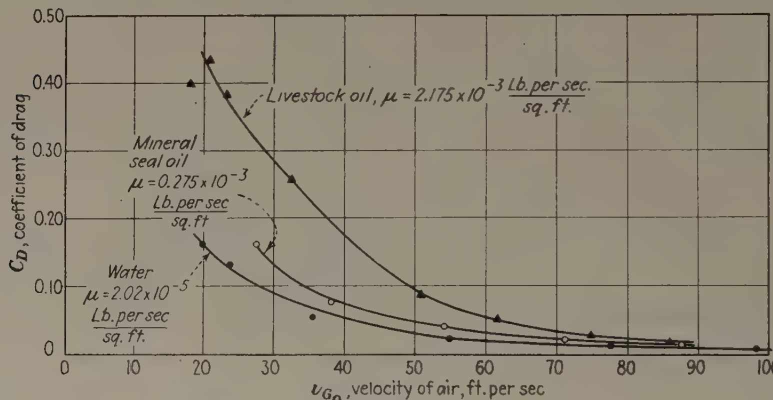

FIG. 12.—COEFFICIENT OF DRAG FOR ANNULAR RING CONDITION.

In selecting a size and type of pipe to give optimum efficiency, it would seem a logical first approximation to choose the pipe that shows a maximum value of

$$\frac{C_D \rho v_G^2}{W_G}$$

based upon conditions at the top. Additional data on variation of pressure and thickness of annulus with depth would permit of more precise comparisons.

ACKNOWLEDGMENTS

The author is indebted to the Department of Petroleum Engineering of the University of California, in the laboratories of which the experiments were conducted, and to the Standard Oil Company of California, which furnished the oils.

Credit is also due to Professors L. C. Uren and M. P. O'Brien, who made many helpful suggestions.

Structure of Clay Gels

By W. K. Lewis,* Lombard Squires and W. I. Thompson

(Houston Meeting, October, 1935)

The authors presented an article[2]† last year on colloidal properties of clay suspensions in which they attempted to sustain the position that the behavior of clay suspensions is due primarily to the mechanical interference of the platy particles, the nature and extent of the interference being profoundly influenced by the character of the surfaces of the particles, which in turn is determined primarily by the nature and amount of adsorbed foreign materials held on the surface of the particles by forces which are predominantly chemical in type. The following discussion is a continuation of that article to extend these same interpretative points of view to the behavior of clay gels. Insight into the mechanism of gelation is certainly of outstanding importance in the handling of drilling muds.

In the former article it was suggested that the thin, flat plates that constitute the ultimate clay particles may build up aggregates by the overlapping of the ultimate plates face to face much longer and perhaps also much wider than the ultimate plates themselves, but not appreciably thicker. Exhaustive microscopic examinations of characteristic clays show no tendency for the larger particles, clearly visible under the microscope, to orient themselves in this way. It is true that the gelation of the clays is due primarily to the smallest particles, unresolvable other than by the ultramicroscope, so that the possibility of the development by them of an overlapping structure is not excluded. Furthermore, as one approaches the limit of resolving power of the microscope, the difficulty of observing accurately the shapes and relative positions of particles increases excessively. However, in the absence of any observable tendency toward overlapping orientation of the large, visible particles, one hesitates to ascribe such a tendency to the smaller particles beyond the range of visibility. Should it develop that one must exclude the assumption of overlapping orientation, the explanations offered in the previous article are changed in only one respect; namely, one would now have to assume that the ultimate particles themselves have length, and probably also width, very large in comparison with their thickness.

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* Massachusetts Institute of Technology, Cambridge, Mass.

† References are at the end.

Interference of Platy Particles

Visualize a relatively dilute suspension of a fine clay, particularly one of highly developed, flaky structure. The ultimate particles suspended in water are in violent Brownian movement, which keeps them in random orientation. If the concentration is somewhat increased as, for example, by a moderate settling of the suspension, the particles will interfere more frequently, and hence the suspension will show higher viscosity. The interference will be almost exclusively edge-on collisions; the surfaces of contact will therefore be small and consequently also the tendency to adhesion. When, however, the concentration reaches a certain point, the particles are packed sufficiently closely so that separation of a particle in contact with its neighbor on one side is prevented by contact with another neighbor on the opposite side. One has thus developed a structure and transformed the suspension into a gel.

This explanation of gelation of clay suspensions is predominantly mechanical in character. It is not intended to give the impression that solvation of the particles and adsorption of solutes upon their surfaces are unimportant. On the contrary, these phenomena can profoundly influence the character of the structure. It does, however, presume that the fundamental factor is mechanical interference of flaky particles.

It is important to keep in mind the character of the arrangement of the particles. Cards thrown on the table arrange themselves almost exclusively parallel to the table surface. One must realize that in clay suspension one has, from the point of view of orientation, the equivalent of a pack of cards suspended in a liquid of the same density as the cards themselves, so that effects of gravity are eliminated. Hence there is no appreciable force tending to arrange the cards in parallel positions. Microscopic examination and all other known facts indicate that the structure of a clay is due to this sort of random orientation of platy particles.*

The development of such a structure into a gel requires the assumption of frictional resistance to slip of the edges of the cards pressing against each other, since otherwise no significant resistance to deformation could be developed at low volumetric concentrations of the suspended particles. It does not require adhesion in the sense of a tensile resistance to separation of the particles, although it is not implied that this is absent. This effect is analogous to that which would be produced if the plates were imagined to have rough saw-toothed edges, which would prevent tangential slip of the edges over a surface but would allow normal separation of the two.

The best evidence that structure of this sort exhibits the phenomena observed is found in the behavior of suspensions of microscopic platy

* This conclusion is independent of the presence or absence of overlapping orientation.

particles. Fig. 1 shows the flow characteristic of suspensions of coarse particles of flake graphite in a mixture of carbon tetrachloride and ethylene tetrabromide of the same density as the graphite. A volumetric concentration of 23 per cent of graphite shows a definite yield point. The graphite employed was carefully screened on a 4-mesh screen and only the particles retained thereon were employed. They disintegrate somewhat on agitation, but all particles are easily visible and range upward to ⅛ in. The data show the characteristic behavior encountered not only in clay suspensions but in solutions of many emulsoids. In this case, however, the effect is certainly mechanical.

The difficulty with this mechanical explanation of gelation of clay suspensions as due to the interference of platy particles comes from the necessity of postulating plates with length and width far greater than their thickness. While graphite flake suspensions show plastic flow, it requires a volumetric concentration of over 20 per cent. Ultra clays, however, will gel at volumetric concentrations of the order of 0.5 per cent. While any quantitative estimate as to the ratio of length (or width) to thickness necessary to explain the behavior of these extremely dilute suspensions depends on assumptions that are decidedly uncertain, it would seem that in the limiting cases the ratio must be of the order of magnitude of 100 to 1, or perhaps even several times this figure. Granting, however, that a particle of dried clay consists of excessively thin plates held face to face by surface forces, dispersion involves merely the peeling off of these plates from the larger aggregate, producing particles of progressively decreasing thickness without substantial reduction in length or width.

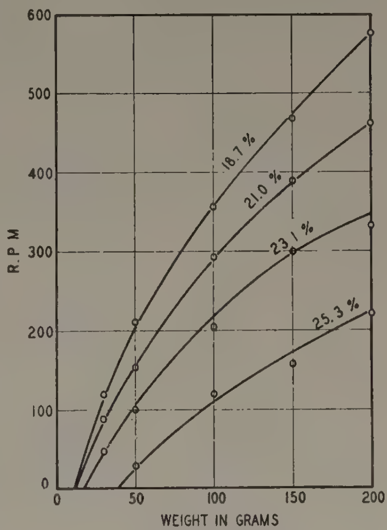

Fig. 1.—Weight-r.p.m. curves for suspensions of graphite in a mixture of carbon tetrachloride and ethylene tetrabromide of same density as the graphite.

Figures on curves are concentrations of graphite used. The graphite was extremely coarse (particles up to ⅛ in. in diameter), the open cup was used, and the run was conducted at room temperature.

The curves of Figs. 1–4 were obtained with a Stormer concentric cylinder viscosimeter. The intercept on the weight axis is called the yield point, and the slope of the curve is called the mobility.

Position of Particles in Settling

While this dispersion of the clay aggregates into the ultimate particles has so far eluded observation, it has proved possible to follow under the

microscope the reverse phenomenon; i.e., the formation of visible aggregates from the ultimate particles in suspension. If a dilute suspension of an ultra clay, all or most of the particles of which are too small to be resolvable, is placed beneath the cover glass on a microscope slide and allowed to stand, the water dries out in a somewhat abnormal manner. Evaporation occurs very slowly from the edges of the liquid under the glass cover. In clay suspensions, the evaporation ceases at specific points on the periphery of the water surface, but proceeds elsewhere along it. In consequence there is a "hang-up" of evaporation at the point in question and the line of demarcation of the water pool recedes in intersecting concave curves. Along this line of evaporation, concentration of the clay particles obviously occurs. Under the microscope one finally observes the formation and growth of clay particles that must constitute aggregates built up from the invisible ultimate particles of the suspension itself. As evaporation goes on, not only do the ultimate particles concentrate at the higher surface but the surface tension of the liquid obviously tends to orient them parallel to the liquid interface. In the largest particles, as the surface of evaporation reaches them this orientation can be observed directly, the particle, initially lying flat on the surface, turning up on edge. This makes it possible and indeed inevitable for the particles to be oriented to parallel to themselves, and consequently to accumulate as larger aggregates of high stability, because of the surface forces holding them together, once the dispersing water has been removed. On the dried slide the aggregates thus accumulated along the curved lines of evaporation show the optical characteristics of minute crystallites, including strong birefringence. A material such as ground silica behaves entirely differently, accumulating without indication of orientation of the ultimate particles.

It appears that so far as the limits of resolution of the microscope allow one to go, the observable ratios of length to thickness are small, of the order of three or at the most four or five to one. However, the well recognized difficulties of determining shape factors under these conditions greatly weakens the force of this fact as an argument against high ratios for the small particles.

That the clay particles in a gel are tightly wedged into position seems indisputable in the light of the microscopic observation of the Brownian movement. A fine clay in dilute suspension shows violent Brownian agitation. The same clay in a concentration sufficient to gel shows almost complete absence of vibration of the particles after gelation has occurred and greatly reduced agitation before gelation develops. There can be no doubt that gelation involves some mechanism that locks the ultimate particles firmly into place in a physical structure. Furthermore, the microscopic examination of the gel fully confirms the random orientation of the particles, despite the fact that in some gels clumping,

undoubtedly due to flocculation, is clearly evident. The only observable change under the microscope that occurs during the process of gelation is this slowing down of the Brownian movement. There is no apparent change of particle distribution as a whole.

Beyond doubt, the process of conversion of a given suspension into a gel is often, if not indeed usually, brought about by settling of the particles. This is probably true even where no settling can be observed and no water separates above the gel, because in such cases the settling merely involves a moderate increase in concentration in the lower portions of the mass, with a diminution at the top insufficient to leave clear liquid. In such cases a true gel structure may not reach quite to the top, but will be so close to it that distinction between fluid above and gel below cannot be drawn. Meanwhile, the random orientation of the particles in the gel itself is maintained by the fact that small platy particles on settling have no tendency to turn but during settling tend to retain their original inclination with the horizontal[3,4].

Adsorption of Water by Clay Particles

It would appear that the only alternative explanation of the gelation of clays that has received serious consideration is the assumption that the clay particles adsorb layers of water sufficiently thick to build up quasi-fluid particles that occupy enough volume to interfere sufficiently to induce gelation[1]. Study of the problem in the light of the fact that gelation actually occurs in extremely dilute suspensions, containing, as stated above, approximately 0.5 per cent by volume of clay particles, indicated that the assumption of solvation as an adequate explanation requires the firm adsorption on the surface of the particles of water layers many molecules thick. Here again quantitative estimation of the thickness of the layers depends on uncertain assumptions, but it seems impossible to postulate layers less than five or six molecules thick. Probably they are much thicker, unless one assumes particle shapes that are of themselves substantially equivalent to the mechanical explanation here offered.* Perhaps the most convincing argument against the adequacy of water adsorption as an explanation of gelation is the extraordinary tensile strength exhibited by clay gels. A gel made up with 10 per cent by volume bentonite in water, tested in the form of a standard tensile test piece one square inch in cross section, showed breaking strengths in

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* It is not proposed to deny the adsorption of water on the surface of the clay. Indeed, as is clear from the previous article, the authors are convinced that this adsorption is a vitally important factor. It does, however, seem untenable to assume that the water thus held is many molecules thick, or, if it is, that the outer layers of such water are held sufficiently firmly to be semi-solid or even equivalent to a non-miscible liquid.

tension of from about 400 to 700 grams. While the percentage variation was large, the magnitude of the effect was unmistakable. It cannot possibly be explained by the surface tension of the sample surface. It is difficult to see how particles with a water surface, even an adsorbed water surface, touching each other could possibly have enough adhesion to give the effect, or enough resistance to sidewise slipping past each other to interfere with the rupture. If, however, one will assume in the sample a mechanical structure made up of interfering clay particles, the behavior of the test piece can be understood. Rupture in tension can occur only by elongation, which requires reduction in cross section of the sample. However, this reduction of cross section is resisted by the mechanical structure of the clay particles. This in turn causes the water, which cannot flow, to exhibit its so-called tensile strength, observable likewise in confined columns in which ordinary flow cannot occur.

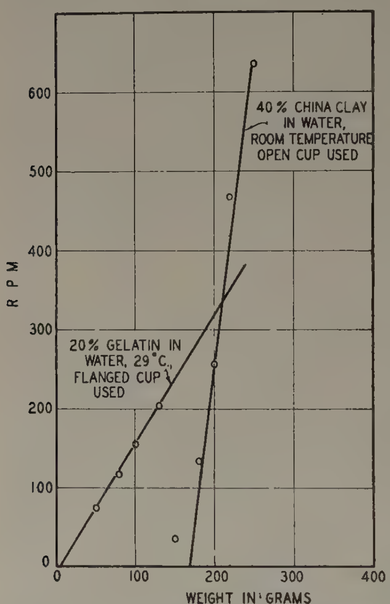

Fig. 2.—Weight-r.p.m. curves for 40 per cent china clay in water, and 20 per cent gelatin in water at the temperature indicated.

Confirmation of Theory of Interfering Platy Structure

The assumption of interfering platy structure as the predominant cause of gelation of clays is also confirmed by the fact that clay suspensions exhibit high mobility relative to their yield point. This is in sharp contradistinction to the behavior of emulsoids, such as gelatin (Fig. 2). As long as the platy particles are actually jammed together in the gel, the contact friction is considerable, because of the force pressing the surfaces against each other. As soon, however, as enough agitation has occurred to cause slippage, the particles separate readily, and the only resistance to flow is the particle interference in the moving filaments of liquid. In consequence, despite the high initial yield point, the viscosity falls rapidly with increasing rate of shear once flow is started. If one prepares a liquid suspension of particles that are clearly unaffected by the liquid suspending medium employed, it is found that, in order to develop a yield point or the equivalent of a gel structure, it is necessary to have concentrations of the particles at least approximately equivalent to the bulk density of the material in question. Thus, if one produces a suspension of ground glass that shows a distinct yield point, it will be found that the concen-

tration of the glass in the suspension, in weight per unit volume, is at least approximately equal to that shown by the same dry, ground glass in bulk (Fig. 3). In other words, mechanical gels require an interfering concentration determined only by the size and shape of the solid particles with which one is dealing. The moment, however, one starts to deal with suspensions of particles that are not inert to the liquid suspending medium, this relation no longer holds. It is, of course, not valid for clays. The reason, however, is obvious from the preceding discussion. The clay

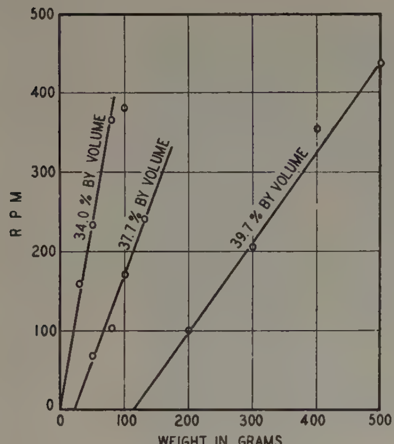

Fig. 3.

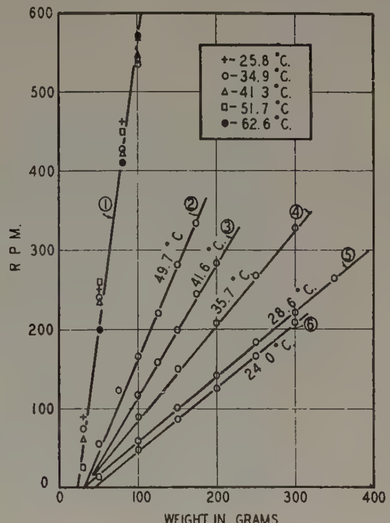

Fig. 4.

Fig. 3.—Weight-r.p.m. curves for suspensions of ground glass in water. The open cup was used, and the experiment was conducted at room temperature. In a 39 per cent by volume suspension, the particles occupy their dry bulk volume.

Fig. 4.—Weight-r.p.m. curves for suspensions of bentonite in different liquids.

Curve No. 1 is for bentonite in water, 2.4 per cent by volume, and temperatures for each point are given. Curves 2, 3, 4, 5 and 6 are for acid-washed bentonite suspended in oil by successive replacement of solvent from water through alcohol, ether, petroleum, ether to oil. Temperatures are indicated on curves. Bentonite in water was tested in open cup with cover and thermometer. Bentonite in oil was tested in flanged cup with thermometer.

aggregates in the dry clay are large, but may be highly dispersed by suspension in water. They then immediately behave like a far finer material, which would have a far lower bulk density were one able to dry down the ultimate particles in this same dispersed condition. A suspension of clay in oil acts like so much ground glass, because the oil has no dispersing power on the dry clay aggregate.

The most impressive confirmation of the explanation of gel structure of clays proposed here is found in the influence of temperature on yield point and mobility. Fig. 4 shows the flow characteristics of a suspension

of clay in a viscous mineral oil.* The yield point is substantially independent of the temperature, but the mobility rises rapidly with the temperature. Table 1 gives the ratio of the fluidity of the oil to the mobility of the suspension: there is no significant change in this ratio. These are

TABLE 1.—*Ratio of Fluidity of Oil to Mobility of Suspension*

Temperature, Deg. C.	Fluidity of Oil Base in Reciprocal Poises = μ_0	Mobility of Bentonite in Oil in Reciprocal Poises = μ	μ_0/μ
24.0	1.33	0.52	2.6
28.6	1.63	0.56	2.9
35.7	2.24	0.81	2.8
41.6	2.94	1.13	2.6
49.7	4.17	1.57	2.7

exactly the characteristics to be anticipated in a mechanical suspension, but it is difficult to see how they could be explained on the basis of solvation, surface adsorption, particularly in a nonpolar medium such as hydrocarbon oil. The behavior of the same clay in water is shown in the same figure. It is by no means simple. The curves for different temperatures are somewhat overlapping and confused. There is certainly no marked change with temperature in either yield point or mobility. These irregularities apparently are due to the excessively thixotropic character of this particular sample in water. The data, however, confirm the conclusion that the predominant effect is mechanical.

It is particularly significant that the plastic characteristics of the clay-in-oil suspension of Fig. 3 are observed at a volumetric concentration of clay of less than 5.5 per cent. This is true despite the fact that the probability of surface adsorption playing a significant role in this case is negligible. In other words, the data confirm the conclusion that mechanical interference of platy particles can develop plastic properties in a suspension, even at these low volumetric concentrations. In the process of solvent replacement by which this suspension was prepared, some agglomeration of the ultimate particles undoubtedly occurred, sufficient to account for the moderate reduction in the plastic characteristics of the suspension.

The importance of the nature of the surface of the ultimate clay particle must never be forgotten. An insight into the nature of the surface forces can be obtained by comparing the behavior of an ordinary bentonite with "bentonitic acid" produced by washing the same clay

* This dispersion was secured by the technique of Kistler; namely, by first producing a water dispersion, gradually replacing the water by progressive additions of alcohol, followed by centrifuging until the water has been completely removed. The alcohol was then replaced in the same manner by ether, the ether by petroleum ether and this finally by the mineral oil.

with acid and then carefully washing out the excess acid. The product of the acid washing is still a highly dispersed clay. If, however, this clay acid is evaporated to dryness, it, like the original bentonite, sets to a hard, rocklike cake. Unlike the original bentonite, however, it cannot, even after grinding, be again dispersed at all readily. See Fig. 5. The hydroxyl groups on the surface of the clay acid have extremely high mutual attractions, and two plain surfaces of the ultimate clay particles face to face are held by the polar attractions of these hydroxyl groups so firmly that it is extremely difficult to pry them apart. However, in the ordinary bentonite these surface hydroxyls have reacted with alkali and alkaline earth metals, and these make it impossible for the ultimate clay

Fig. 5.—Relative dispersion of ordinary bentonite and acid bentonite.

Bottle 1 contains ordinary bentonite dispersed in water to 2 per cent suspension, evaporated and dried at 110° C., ground and redispersed to original concentration in water. Bottle 2 contains acid-washed bentonite treated in exactly same way. Both suspensions were allowed to settle three days before photographing.

surfaces on drying to approach anything like as closely as they can do in the clay acid. Consequently, this makes possible the more ready entrance of water between the plates and, as the metals are hydrophilic, aids in drawing in that water. Consequently, the ground metal containing bentonite disperses readily, whereas the dry bentonitic acid resists dispersion in remarkable degree. On the other hand, the bentonitic acid particles were originally highly dispersed. Therefore they have a layer of adsorbed water on their surface which prevents agglomeration, because the forces holding the adsorbed water on the surfaces of the ultimate clay particles are stronger than the mutual attractions of the clay surfaces for each other. Drying, however, forcibly removes the separating layer of adsorbed water and, once removed, it is again restored only with difficulty.

The effect of pH and of addition agents can be profound, owing both to increasing or decreasing dispersion and to changing the degree of

friction and adhesion between particles in actual contact. On the other hand, detailed discussion of such factors is beyond the scope of this article.

Study of the complicated facts indicates that the fundamental cause of gelation of clays is mechanical interference of platy particles, and that other factors, however important they may be, are secondary. It is believed that a recognition of these relationships offers the only sound basis for a fruitful study of the gelation behavior of clays.

Acknowledgment

This article is based in no small degree on the results of a number of workers engaged in these laboratories during the last year on a study of the properties of clays, and the authors wish to give them full credit for their contributions. Most important and helpful has been the microscopic work of Dr. L. S. Brown, to which reference has been made repeatedly.

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Determination of Surface Tension and Specific Gravity of Crude Oil under Reservoir Conditions

By D. T. Jones*

(Houston Meeting, October, 1935)

In view of the importance of the application of scientific principles to the production of oil from the reservoir, the Production Staff of the Anglo-Iranian Oil Co. (late Anglo-Persian Oil Co.) has been engaged for some years on an intensive program of research on the physical properties of crude oil. Problems involving the retention of crude oil in capillaries and fine fissures demanded for their solution a knowledge of the surface tension and specific gravity of the crude under reservoir conditions, and it is the purpose of this paper to describe briefly the methods adopted for the determination of these properties, and to present the more important results. A detailed article was published in volume 1 of the World Congress *Proceedings* (1933).

Surface-tension observations on crude oil regassed at high pressures with natural gases have been made in the past by Beecher and Parkhurst[1] and Swartz[2], but up to the time of the investigations in Iran no one seems to have carried out experiments with gas-saturated crude direct from the reservoir and kept at its original pressure. Results obtained in this manner are obviously of greater practical value for solving problems connected with the reservoir.

Method of Measurement

No apparatus for the measurements, under the pressure conditions involved, was available, and a suitable instrument had to be designed and constructed in the Fields workshops. Careful consideration of the matter led to the adoption of a method for measuring the surface tension which did not involve a knowledge of the specific gravity of the oils under the working conditions: the main reason for this being that up to that time no accurate determination of the specific gravity had been made under these conditions. The method adopted involves the measurement of the actual tension in an oil film, and is effected by means of

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[1] C. E. Beecher and I. P. Parkhurst: Effect of Dissolved Gas upon the Viscosity and Surface Tension of Crude Oil. Petr. Dev. and Tech. in 1926, A.I.M.E. (1927) 51.

[2] *Physics* (1931) **1**, No. 4.

an electromagnetic balance. Fig. 1 shows the principle of the method. The tension in the film $AA_1 B_1B$, formed by dipping the glass frame into the liquid, as far as the cross-piece AA_1, and then withdrawing it to a certain level, is balanced by the repelling force between the magnetic pole S of the balance beam NS and the electric solenoid N_1S_1. The current through the solenoid may be delicately adjusted by means of a rheostat, and its value for the balanced condition, as measured by the meter M, is a measure of the surface tension of the liquid under the

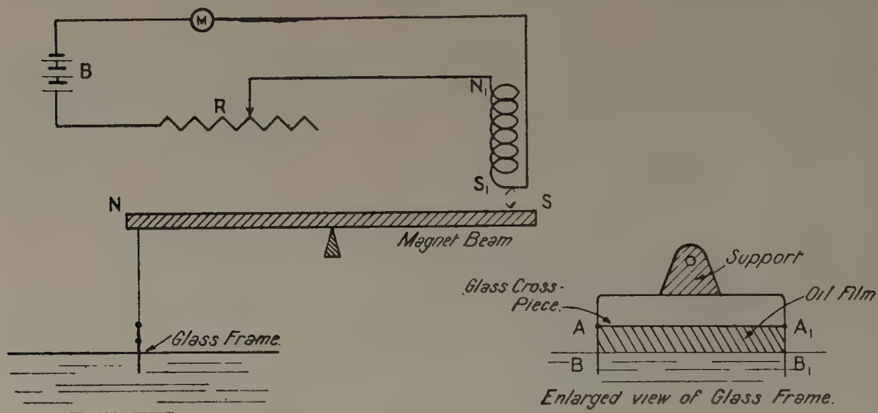

FIG. 1.—PRINCIPLE OF METHOD.

given conditions. The surface tension in absolute units may be determined by a series of calibrations, repeated regularly throughout the whole investigation. For these calibrations, a number of small, known weights are suspended from the glass frame, and the currents for balance are noted. Observations on two or three oils of known surface tension under atmospheric pressure, as measured by the method of capillary rise, then furnish a constant factor that enables a direct conversion of meter readings into values of the surface tension to be made.

On completion of the surface-tension measurements, a number of specific-gravity observations were made by suspending from the balance beam a glass bob in place of the frame, in a manner similar to the Westphal balance. A calibration curve showing "repelling current for balance" plotted against "specific gravity" having been previously determined for liquids of known specific gravities, the specific gravity of the liquid under investigation could be directly deduced.

The Apparatus

Photographs of the apparatus are given in Fig. 2 and Fig. 3 shows diagrammatically the arrangements of the components. The surface-tension balance itself is made in two halves, as shown in Fig. 2, which are bolted together by four massive bronze bolts. The two halves, when

bolted together, come into intimate contact over two circular joints. The inner one is the high-pressure joint, which forms the outside bound-

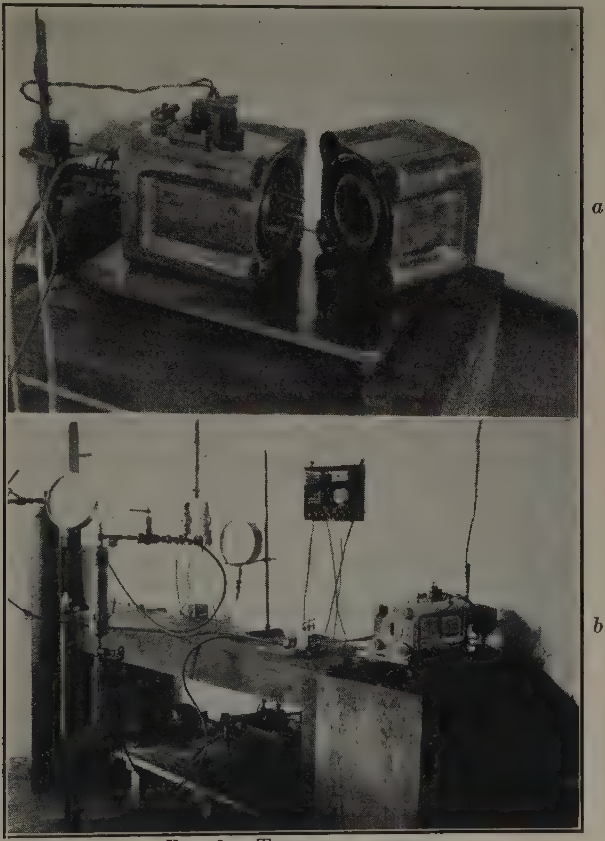

FIG. 2.—THE APPARATUS.

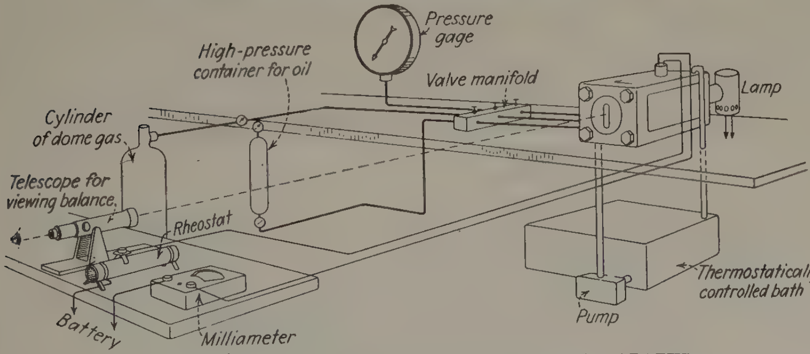

FIG. 3.—ARRANGEMENT OF COMPONENTS OF APPARATUS.

ary of the chamber containing the beam and the sample under high pressure. The outer joint serves only as a seal to the water jacket that

surrounds the inner chamber, and need therefore not be very tight. The apparatus is made almost entirely of manganese bronze.

The magnetic beam is supported on two hard steel points resting on jewels. Its motion relative to a fixed scale is observed through a high-pressure glass window from a distance of about 8 ft., by means of a telescope. The observations are facilitated by a beam of light, which is projected through the instrument from the rear. For ease of control, the rheostat *R* and the milliammeter *M* are placed beside the observing telescope (Fig. 3). Very fine control is obtained, and the use of the telescope, with its high magnification, increases considerably the accuracy of the measurements.

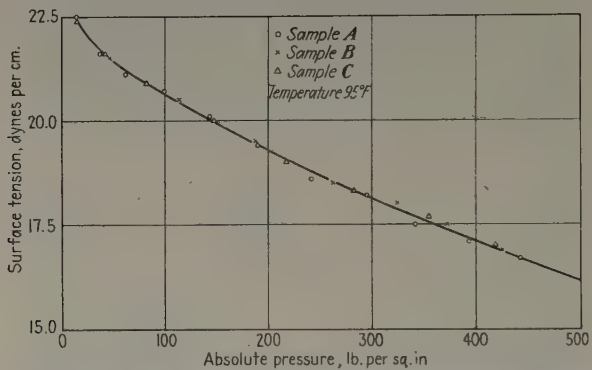

FIG. 4.—VARIATION OF SURFACE TENSION OF RESERVOIR CRUDE WITH SATURATION PRESSURE.

Gas and oil connections, of ⅛-in. copper pipe, lead from the balance to a small valve manifold, and from thence connections are made by flexible high-pressure hoses. The oil sample is contained in a small steel chamber, and high-pressure reservoir gas for charging the system is furnished by the large gas cylinder on the left. The balance itself rests on a concrete column, and the oil sample is kept at a constant temperature by circulating water through the water jacket from a thermostatically controlled water bath. A thermometer pocket incorporated in the instrument enables the temperature of the sample to be accurately registered.

EXPERIMENTAL PROCEDURE

In these experiments the properties of the crude oil were investigated under varying conditions of temperature and saturation pressure. The observations were taken on samples obtained from the reservoir by means of a bottom-hole sample-taker, and their pressure was not allowed to fall before the commencement of the experiment. The complete apparatus, prior to the introduction of the sample, had been charged to the required pressure with gas from the reservoir, and the sample was then transferred under pressure from the sample-taker to the steel chamber. The intro-

duction of the oil into the balance was effected by raising and lowering the container, and by judicious manipulation of the valves.

Results of the Investigations on Crude

Surface Tension.—Fig. 4 shows the results of three experiments at 95° F. carried out on three entirely different occasions, on samples from

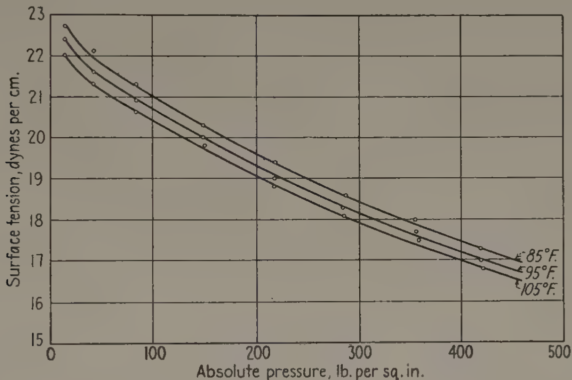

Fig. 5.—Surface tension of saturated crude at different temperatures.

two different parts of the field. There is good agreement between the three sets of results, and the surface tension varies appreciably with the saturation pressure, decreasing from 22.4 dynes per centimeter at atmospheric pressure to 16.2 dynes per centimeter at 500 lb. per sq. inch.

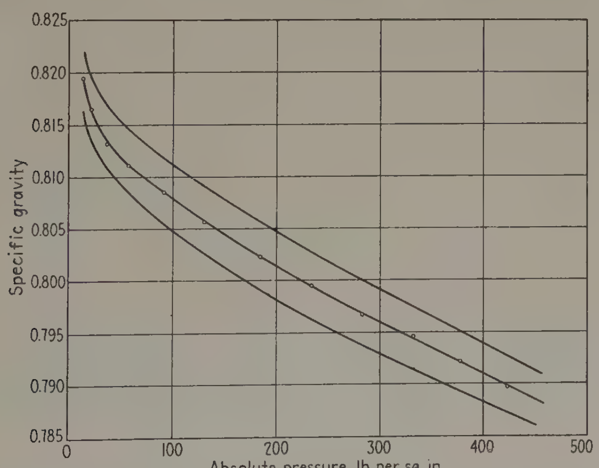

Fig. 6.—Relation between specific gravity of Iran crude and saturation pressure.

A series of measurements were also made at temperatures of 85° F., 95° F. and 105° F. The results are shown in Fig. 5, and indicate a

temperature coefficient of the order of 0.03 dyne per centimeter per degree Fahrenheit.

Specific Gravity.—The results obtained for the specific gravity of gas-saturated crude, at temperatures of 85° F., 95° F. and 105° F., are shown in Fig. 6. At 95° F. the specific gravity decreases from 0.819 at

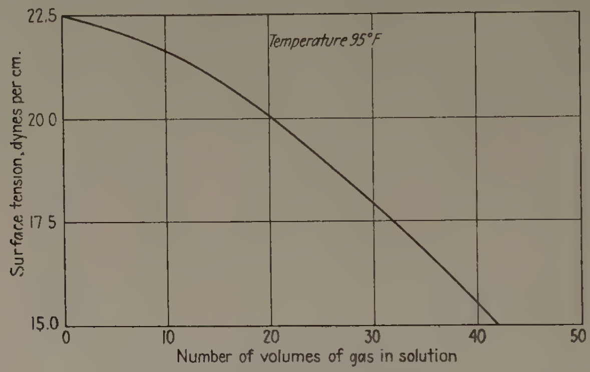

Fig. 7.—Variation of surface tension of saturated crude with number of volumes of gas in solution.

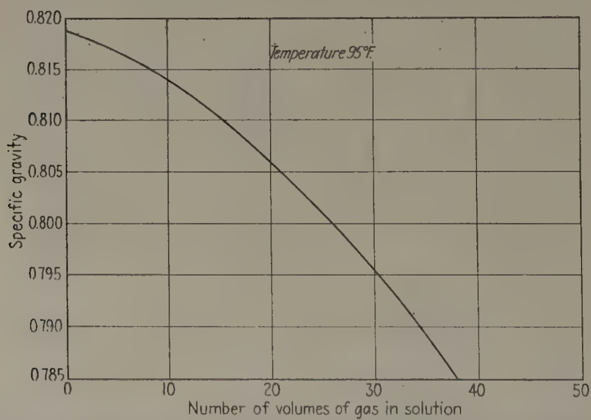

Fig. 8.—Variation of specific gravity of saturated Iran crude with number of volumes of gas in solution.

atmospheric pressure to 0.786 at a pressure of 500 lb. per sq. in. The temperature coefficient remains practically constant over the entire range of pressures, and is equal to 3.3×10^{-4} per degree Fahrenheit.

Other Results of Interest

It will be noticed in Figs. 4, 5 and 6 that as the saturation pressure is decreased a marked change occurs in the slope of the curves when a pressure of 45 to 50 lb. per sq. in. is reached. Investigations on the gas

content of saturated Iran crude have shown that as the pressure is lowered a fairly uniform evolution of gas takes place until a pressure of about 50 lb. per sq. in is reached, and then there is a very considerable increase in the rate of evolution. One might expect, therefore, that curves showing the relation between surface tension (or specific gravity) and the number of volumes of gas in solution might be fairly uniform in character, and the curves in Figs. 7 and 8 show that there is no longer any sudden change at a pressure of about 50 lb. per sq. in. It should be noticed, too, that the influence of the light fractions at the higher pressures is very marked. Thus, a reduction of the gas content by 10 volumes at 400 lb. per sq. in. leads to an increase of 0.010 in specific gravity, while the corresponding increase at pressures near atmospheric is only 0.005.

A number of observations were made on distillates and residues (all single flash products), at a temperature of 95° F., and it is interesting to compare the results with the values for crude, given in the following table:

Sample	Specific Gravity	Surface Tension
Iran crude at atmospheric pressure (no weathering)	0.819	22.4
Iran crude saturated at 500 lb. per sq. in.	0.786	16.2
15 per cent distillate at atmospheric pressure	0.699	17.0
30 per cent distillate at atmospheric pressure	0.722	18.5
77.5 per cent residue at atmospheric pressure	0.858	25.7
45 per cent residue at atmospheric pressure	0.899	27.4

It will be noticed that the surface tension of gas-saturated crude at 500 lb. per sq. in. is actually less than that of 15 per cent distillate at atmospheric pressure.

Values for the surface tensions of some American crudes at atmospheric pressure at a temperature of 88° F. have been given by Swartz, and it is of interest to compare these with the values for Iran crude, as follows:

Crude	Specific Gravity	Surface Tension
Iran from flow tank (slightly weathered)	0.824	22.7
Iran from sample-taker (unweathered)	0.821	22.6
Sugarland, Texas	0.880	28.6
Lima, Ohio	0 816	25.2
Santa Fe Springs, California	0.845	26.0
Salt Creek, Wyoming	0.816	25.3

Compared with the other crudes, the surface tension of Iran crude appears low, but in view of the fact that the American crudes had very

probably suffered considerable weathering before the measurements were made, the result is not surprising.

Acknowledgments

The research staff of the Production Department is indebted to the Chairman and the Directors of the Anglo-Iranian Oil Co. for permission to publish this paper.

An Investigation of Experimental Methods of Determining Sucker-rod Loads*

By Emory Kemler†

(New York Meeting, February, 1936)

The problem of determining the most desirable operating conditions of an oil-well pumping unit, the selection of the proper material and size of sucker rods, and the design of the pumping unit, requires that the sucker-rod loads be known with a reasonable degree of accuracy. In production practice, it is also desirable to know the effects of operating speeds and strokes on a plunger motion, as well as on the rod loads.

For a particular well, data on rod loads can be obtained by measuring the load in sucker rods with a dynamometer. This method is not satisfactory because it does not permit the various factors to be investigated independently. It is also impossible to measure the plunger motion simultaneously with rod motion under operating conditions. The mathematical solution is impractical because of the simplifications that have to be made to get a solution and the tremendous amount of numerical work that is necessary after such a simplified solution has been attained. This paper shows how analogies and models can be applied to the solution of these problems.

The loads set up in a sucker-rod string during the ordinary pumping cycle are made up of the weight of the rods, force required to accelerate the rods, weight of the oil and force required to accelerate the oil on the upstroke, rod friction, stuffing-box friction, plunger friction, friction of the oil in the tubing and rods, and friction loss through the valves. The problem of determining the sucker-rod load is further complicated by the fact that the long oil column and the sucker-rod column act as springs, which affect the transmission of the polished-rod motion. A further complication is the fact that the motion cannot be transmitted at a speed greater than that of the velocity of sound in the material, and this means that there will be a time lag in the transmission in the motion, as well as a modification of its magnitude and a phase displacement.

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* Part of the material of this paper is from a thesis presented in partial requirements for the degree of Doctor of Philosophy at the University of Pittsburgh. Manuscript received at the office of the Institute Dec. 10, 1935.

† Engineering Division, Gulf Research and Development Corporation; Assistant Professor of Mechanical Engineering, University of Pittsburgh.

These complications, combined with the discontinuous nature of the loading as caused by the valve action, makes any elementary analysis unreliable unless the results can be verified by experimental means.

For a mathematical expression of the problem, the above statements must be written in terms of mathematical symbols. The forces acting on the element will be the elastic forces, the weight of the element, the inertia forces and the frictional forces on the sides of the rods. The elastic force P can be calculated from the strain. The force P will then be equal to $AE\frac{\partial y}{\partial x}$ since $\frac{\partial y}{\partial x}$ is the unit strain, or $P = AE\frac{\partial y}{\partial x}$ and $\frac{\partial P}{\partial x} = AE\frac{\partial^2 y}{\partial x^2}$ for a unit length or over a distance dx, $\frac{\partial P}{\partial x}\,dx = AE\frac{\partial^2 y}{\partial x^2}\,dx$. The inertia force will be equal to $\frac{W\,dx}{g}\,a = \frac{W}{g}\frac{\partial^2 y}{\partial t^2}\,dx$ where W = weight per unit length, and a is the acceleration of the element. The frictional force on a length dx will be equal to Fdx if F is defined as the pounds resistance per unit length. F, however, will be assumed to vary with the velocity of the rod, and then will equal $C\frac{\partial y}{\partial t}$ where C will be the pound resistance per unit velocity per foot.

Writing the equation for equilibrium of the forces, we find

$$P + \frac{W}{g}\frac{\partial^2 x}{\partial t^2}\,dx + C\frac{\partial y}{\partial t}\,dx - \left(P + \frac{\partial P}{\partial x}\,dx\right) - W\,dx = 0$$

Substituting for $\frac{\partial P}{\partial x}\,dx$ and simplifying the equation reduces to

$$\frac{W}{g}\frac{\partial^2 y}{\partial t^2} + C\frac{\partial y}{\partial t} = AE\frac{\partial^2 y}{\partial x^2} + W$$

Similar equations can be written for the oil and tubing columns, as follows

$$\frac{W_0}{g}\frac{\partial^2 z}{\partial t^2} + C_0\frac{\partial z}{\partial t} = A_0E_0\frac{\partial^2 z}{\partial x^2} + W_0$$
$$\frac{W_t}{g}\frac{\partial^2 U}{\partial t^2} + C_t\frac{\partial U}{\partial t} = A_tE_t\frac{\partial^2 U}{\partial x^2} + W_t$$

where the subscript 0 stands for the oil column and z represents the coordinate which defines the motion of the oil column. The subscript t and U represent corresponding conditions in the tubing column.

These three equations specify the motion of every part of the system if the proper boundary conditions are given. The boundary conditions that apply to this problem are rather complicated. We know that the rod column executes the motion:

$$y = f(t) \text{ at } x = 0. \qquad [1]$$

At the top of the well, the oil column will be under zero stress if it discharges into a tank under no pressure so that:

$$\frac{\partial z}{\partial x} = 0 \text{ at } z = 0 \tag{2}$$

During the upstroke, the bottom of the oil and rod columns coincide, which means that $y = z$ at $z = l$, and the load in the oil column and rod column is the same at $x = l$. The time during which this relation holds is not known since the upstroke and downstroke periods are not known. If ϕ equals the lag of the plunger behind the polished rod (assuming steady-state conditions) and ω = rad/sec. = angular speed, the time for ½ revolution or ½ cycle will be $\frac{1}{2} \cdot \frac{2\pi}{\omega} = \frac{\pi}{\omega}$, and for the 1 cycle will be $2\pi/\omega$. The downstroke of the plunger is defined by $\phi < t < \left(\frac{\pi}{\omega} + \phi\right)$, and the upstroke by $\left(\frac{\pi}{\omega} + \phi\right) < t < \left(\frac{2\pi}{\omega} + \phi\right)$. We can then write for the upstroke:

$$y = z \text{ at } x = l \text{ for } \left(\frac{\pi}{\omega} + \phi\right) < t < \left(\frac{2\pi}{\omega} + \phi\right) \tag{3}$$

For the downstroke the boundary conditions are that the lower end of the oil column moves with the tubing and that the stress in the rod column at the bottom is zero. We can then write for the latter, thus:

$$\text{at } x = l, \frac{\partial y}{\partial x} = 0 \text{ for } \phi < t < \left(\frac{\pi}{\omega} + \phi\right) \tag{4}$$

And for the former:

$$x = l, z = U \text{ for } \phi < t < \left(\frac{\pi}{\omega} + \phi\right) \tag{5}$$

The boundary conditions that apply to the tubing column are that there shall be no motion at the top of the column, no stress at the bottom of the tubing on the upstroke of the pump, and that the load in the oil and tubing be the same on the downstroke of the plunger at $x = l$. These conditions can be represented by the following equations:

$$U = 0 \text{ at } x = 0 \text{ for all values of } t \tag{6}$$

$$\frac{\partial U}{\partial x} = 0 \text{ at } x = l \text{ for } \left(\frac{\pi}{\omega} + \phi\right) < t < \left(\frac{2\pi}{\omega} + \phi\right) \tag{7}$$

$$A_0E_0 \frac{\partial z}{\partial x} \text{ at } x = l,\ \phi < t < \left(\quad + \phi\right) \tag{8}$$

We can write for the last condition that the load in the rods and oil column shall be the same on the upstroke, or:

$$AE\frac{\partial y}{\partial x} = A_0E_0\frac{\partial z}{\partial x} \text{ at } x = l; \left(\frac{\pi}{\omega} + \phi\right) < t < \left(\frac{2\pi}{\omega} + \phi\right) \qquad [9]$$

Mechanical Models

The difficulties encountered in making a mathematical analysis and the tremendous amount of numerical work required to carry out the computation on any particular well makes some other method of solution desirable. A method that gives a physical picture of what is going on in the system is highly desirable. The use of a small-scale model of an actual well immediately suggests itself. In using a model of an actual well, the differential equations will be satisfied, but it is necessary to properly select the proportions of the model so that it will reproduce the behavior of the actual system. The dimensions, speed and stroke of such a model must be such that the measurements of the forces and motions on the model will make it possible to compute the corresponding quantities on the actual well. If the motions and displacements are identically proportional, the loads and stresses will likewise be proportional.

We will consider again the differential equation:

$$\frac{W}{g}\frac{\partial^2 y}{\partial t^2} + C\frac{\partial y}{\partial x^2} = AE\frac{\partial^2 y}{\partial x^2} + W$$

Making the substitutions:

$$\frac{y}{l} = y_1; \frac{x}{l} = x_1; t\omega = t_1,$$

$$\frac{\partial^2 y}{\partial t^2} = l\omega^2\frac{\partial^2 y_1}{\partial t_1{}^2}; \frac{\partial y}{\partial t} = l\omega\frac{\partial y_1}{\partial t_1}\frac{\partial^2 y}{\partial x^2} = \frac{1}{l}\frac{\partial y_1{}^2}{\partial x_1{}^2}$$

Substituting these values in equation 1, we obtain:

$$\frac{Wl\omega^2}{g}\frac{\partial^2 y_1}{\partial t_1{}^2} + Cl\omega\frac{\partial y_1}{\partial t_1} = \frac{AE}{l}\frac{\partial^2 y_1}{\partial x_1{}^2} + W$$

Dividing by AE/l

$$\frac{Wl^2\omega^2}{AEg}\frac{\partial^2 y_1}{\partial t_1{}^2} + \frac{Cl^2\omega}{AE}\frac{\partial y_1}{\partial t_1} = \frac{\partial^2 y_1}{\partial x_1{}^2} + \frac{Wl}{AE}$$

Since $\frac{\partial^2 y_1}{\partial t_1{}^2}$; $\frac{\partial y_1}{\partial t_1}$, and $\frac{\partial^2 y_1}{\partial x_1{}^2}$ are now dimensionless, the coefficients of each term must be dimensionless. We can write: $C_1 = \frac{Wl^2\omega^2}{AEg} = \frac{\rho l^2\omega^2}{Eg}$, $C_2 = \frac{Cl^2\omega}{AE}$, $C_3 = \frac{Wl}{AE} = \frac{\rho l}{E}$, where ρ = density of rod column =

W/A = lb. per cu. ft. In order that the two systems may be equivalent, it is, therefore, necessary to have the dimensionless constants C_1, C_2, and C_3 of the actual well and model equal. Using the subscript m for the model, we must have: $\frac{\rho_m l^2{}_m \omega_m{}^2}{E_m g} = \frac{\rho l^2 \omega^2}{Eg}$, $\frac{C_m l^2{}_m \omega_m}{A_m E_m} = \frac{Cl^2\omega}{AE}$, and $\frac{\rho l}{E} = \frac{\rho_m l_m}{E_m}$.

A 10-ft. model of a 3000-ft. well making thirty 5-ft. strokes per minute and using ¾-in. sucker rods would have to operate at 519 strokes per minute, the rods would be replaced by a steel spring having an effective modulus of 10^5 lb. per sq. in., and the friction per foot per unit velocity would have to be 5190 times that in the well. Similar calculations could be made for the oil and tubing columns. To get sufficient elasticity in the oil column, it would be necessary to use air chambers at various points along the column.

These calculations for the rod column show that a mechanical model of which the performance will be similar to that of the actual well is not practical.

Electrical Analogies

The fact that many different physical phenomena can be represented by the same or similar equations permits the results found in one field of science to be used in another. In some fields of science the phenomena can be measured experimentally; whereas it is not practical to do so in another. For instance, the torsion of circular bars of variable cross section has been studied by the use of an electrical model, the torsion of noncircular bars of uniform section has been studied by using a soap bubble, the vibration of mechanical systems has been studied using an electrical model, the action of hydraulic manifold systems can be studied by the use of electrical systems, mechanical systems have been designed to show how electrical systems operate, hydrodynamical systems have been used to determine stresses in noncircular bars subjected to torsion, et cetera.

The use of an electrical model to represent a model oil well has been suggested by Dr. Muskat as a possible method of studying sucker-rod stresses. This method of studying sucker-rod stresses presents the possibility of a convenient method of determining sucker-rod loads, which will be investigated.

The conditions to be required of the electrical model are: (1) that the differential equation for the electrical system be identical in form with that of the mechanical system and (2) that the boundary conditions be the same for the two systems.

The telegraphist or transmission line equation without leakage conductance is: $L\frac{\partial^2 Q}{\partial t^2} + R\frac{\partial Q}{\partial t} = \frac{1}{K}\frac{\partial^2 Q}{\partial x^2}$, where L = inductance, Q = charge, R = resistance, K = capacitance, x = distance, t = time.

This equation is similar to the mechanical equation except for the term to account for the static weight. However, by making a suitable change of variable, this static-weight term can be transformed out of the equation and the two will become similar. If in equation 5 the substitution $y = \bar{y} - \frac{Wx^2}{2AE} + \frac{Wlx}{AE} - \frac{Wl^2}{2AE}$ be made, equation 5 will become:

$$\frac{W}{g}\frac{\partial^2 \bar{y}}{\partial t^2} + C\frac{\partial \bar{y}}{\partial t} = AE\frac{\partial^2 \bar{y}}{\partial x^2}$$

A comparison of equations shows that the following quantities are identified with each other: $\frac{W}{g} \rightarrow L$, $\bar{y} \rightarrow Q$, $C \rightarrow R$, $AE \rightarrow 1/K$, $x \rightarrow x$, $v \rightarrow i \rightarrow \frac{\partial y}{\partial t} \rightarrow \frac{\partial Q}{\partial t}$, $F \rightarrow e \rightarrow AE\frac{\partial y}{\partial x} \rightarrow \frac{1}{K}\frac{\partial \bar{y}}{\partial x}$, where i = current, v = velocity, F = force, e = voltage.

If we now let $\bar{y} = ly_1$; $x = lx_1$ and $\omega t = t_1$, the above equation can be reduced to a dimensionless form as before and supplies two dimensionless constants: $C_4 = \frac{W}{g}\frac{l^2\omega^2}{AE} = \frac{\rho l^2\omega^2}{gE}$, $C_5 = \frac{Cl^2\omega}{AE}$

By substituting the corresponding electrical quantities, we get: $C_4 = \frac{\rho l^2\omega^2}{gE} = Ll^2\nu^2K = \bar{L}\bar{K}\nu^2$, $C_5 = \frac{Cl^2\omega}{AE} = Rl^2K\nu = \bar{R}\bar{K}\nu$, where $\bar{R}, \bar{L}, \bar{K}$ are total resistance, inductance and capacitance of the electrical circuit; R, L, and K being the values per unit length. ν is the frequency of the electrical system. Similar equations are obtained for the oil and tubing columns.

When the change in variable is made in the differential equation it is also necessary to make a similar change in the boundary conditions. When in their new form it is seen that one of the dimensionless constants has in effect been transferred to them. The transform boundary equations show that it is necessary to put a negative voltage in each of the columns to correspond to the static weight. This can be accomplished by using a battery with proper voltage.

The Electrical Circuit

The electrical circuits used in the tests made to try out this method are shown schematically in Figs. 1 and 2. In these circuits, no provision was made for the tubing column. This corresponds to no movement of the tubing column, and the condition corresponding to anchoring of the tubing in oil-field production practice. The valves in the pump are represented by rectifiers that will pass current in one direction and have an infinite resistance to the flow of current in the other direction. The two valves or rectifier tubes as shown in Fig. 1 represent the condition in which oil is pumped only on the upstroke. Fig. 2 represents the case

where oil is pumped on both the upstroke and downstroke. In this circuit, two additional rectifiers are required in order to have movement in the oil column take place always in the same direction. This is accomplished by using a resistance in the rectifier line which permits the current

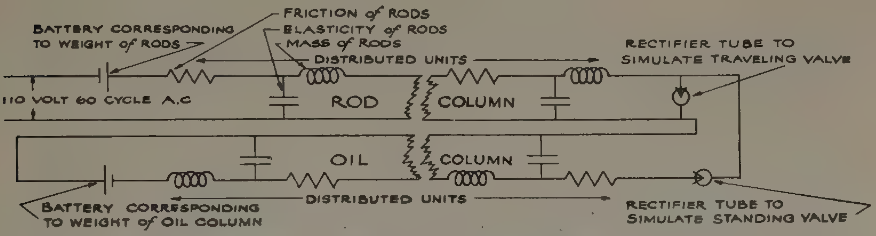


FIG. 1.—ELECTRICAL CIRCUIT WHEN OIL IS PUMPED ON UPSTROKE.

to be shorted across the oil line. By varying this resistance, any amount of current passing in the rod line on the downstroke can be made to pass through the oil line. While it is not practical and desirable, from an

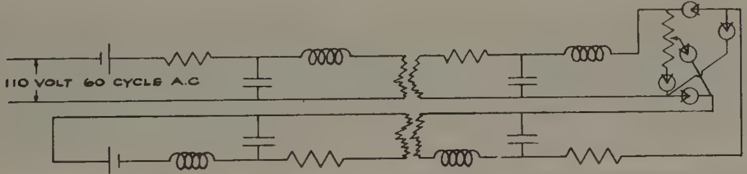


FIG. 2.—ELECTRICAL CIRCUIT WHEN OIL IS PUMPED ON BOTH UPSTROKE AND DOWNSTROKE.

operating point of view with present equipment, to pump any large amount of oil on the downstroke, there is a small displacement equal to the area of the sucker rod times the plunger movement, which cannot be

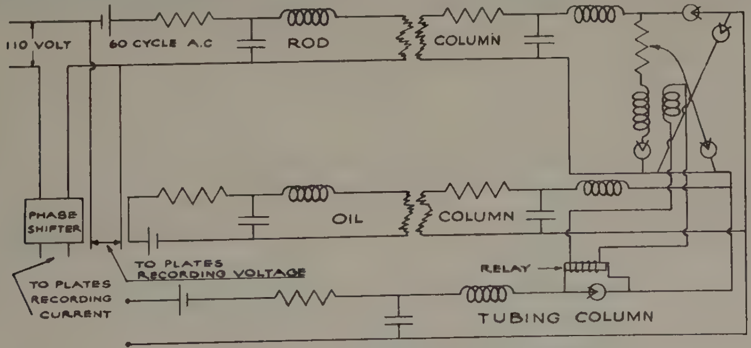


FIG. 3.—CIRCUIT WHEN TUBING IS NOT ANCHORED.

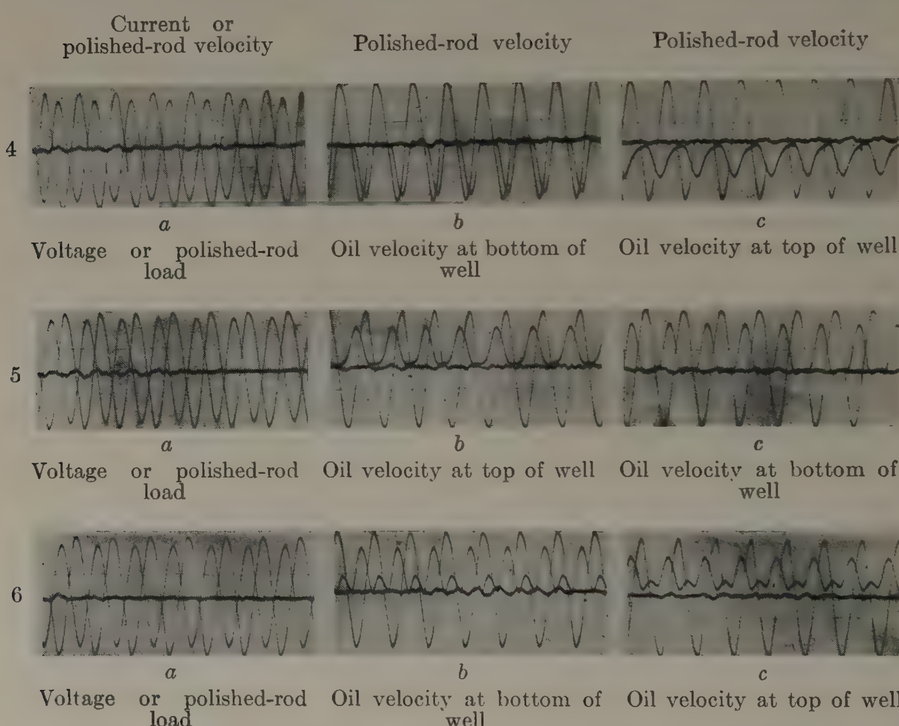
avoided, and the circuit as shown in Fig. 2 makes it possible to take account of this condition.

Fig. 3 shows the circuit when the tubing is not anchored. In this case, it is necessary to use a relay in the traveling-valve circuit, so that

when this valve opens as the pump plunger starts down, the tubing and oil columns will be connected. The oil column's voltage or weight causes the tubing column condensers to be charged, which corresponds to a stretching of the tubing on the downstroke of the plunger.

Experimental Results

The tests on the electrical model were made with the idea of showing the type of data that can be obtained with such a model, and to determine



Figs. 4–6.—Sample results obtained with a moving-film oscillograph.

whether the quantities are of such an order of magnitude that they can be measured and recorded. To show more clearly the nature of the problem, tests were made with an ordinary oscillograph using a moving film and with a cathode-ray oscillograph.

Figs. 4, 5 and 6 show sample results obtained with a moving-film oscillograph. Fig. 4*a* shows the input current or polished-rod velocity and the input voltage or polished-rod load. The curve having the larger amplitude is the current curve, and the curve with the smaller amplitude is the voltage curve. Unfortunately, these two variables were not recorded in the same phase relation, so the phase relation between them is not clearly shown. They are shown 180° out of phase. Fig. 4*b*

shows the relation between the polished-rod velocity and the oil velocity. The upper half of the current curve represents the downstroke of the rods. A short time after the start of the upstroke of the rods, the oil starts to move. This time represents the lag of the plunger motion behind the polished-rod motion. After the half wave giving the oil velocity is completed, it is soon that the rectifier acts, and no current flows until the plunger starts again on the upstroke. Fig. 4*c* shows the relation between the polished-rod velocity and the oil velocity at the top of the well. The oil velocity for this circuit is almost ¼ cycle out of phase with the polished-rod motion. The elasticity of the oil column results in the oil flowing for almost the entire cycle. The flow does, however, drop off rather rapidly near the start of a new pumping stroke.

Fig. 5 shows the same data as Fig. 4, except that the circuit used in Fig. 5 had a less elastic oil column. In the tests shown in Fig. 5, the elasticity was made greater than for a solid oil column. Such a condition would exist in a well where free gas is produced in appreciable quantities

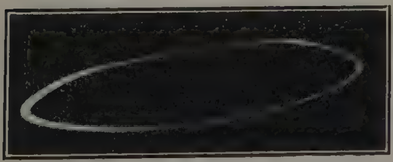


FIG. 7.

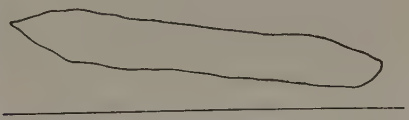


FIG. 8.

FIG. 7.—DYNAMOMETER CARD OBTAINED WITH CATHODE-RAY OSCILLOGRAPH.
FIG. 8.—DYNAMOMETER CARD TAKEN ON A WELL.

with the oil. From a comparison of Figs. 4 and 5, it can be seen that the increased elasticity results in a greater lag between the oil motion and the polished-rod motion and that the peak oil velocity is reduced and the flow continues over a longer period.

The results shown in Fig. 6 are for a well where oil is pumped on the upstroke and downstroke. The elasticity in this case is the same as used in the tests shown in Fig. 5. The curve, Fig. 6*b*, showing the oil velocity at the bottom of the well is seen to have two half-wave curves for each cycle. The larger wave represents the oil velocity on the upstroke, and the shorter wave the oil velocity on the downstroke. Fig. 6*c* shows that the oil flows continuously at the top of the well but that there are still peaks corresponding to the peaks at the bottom of the well.

The diagrams as shown in Figs. 4, 5 and 6 are very useful for studying the relation between the polished-rod motion, plunger motion and oil motion. It can be used to study the effect of speed and other operating conditions on volumetric efficiency, as the area under the velocity curve over a cycle represents the displacement of the plunger.

It is also possible to use a cathode-ray oscillograph to obtain from the model a load-displacement or dynamometer card (Fig. 7). Fig. 8 shows

a card taken on a well. These two cards do not differ greatly in detail and demonstrate that the method is practical. This set-up can be used to study the effect of operating conditions on the shape of the dynamometer rod.

Acknowledgment

The author is indebted to Dr. Morris Muskat of the Gulf Research Laboratories, with whom this problem was frequently discussed and who suggested the application of the electrical analogy to the problem. The writer also wishes to express his appreciation to Mr. R. J. S. Pigott, of the Gulf Research Laboratories, and Prof. John A. Dent, of the University of Pittsburgh, who have made suggestions; and to Dr. Paul D. Foote, Executive Vice President of the Gulf Research and Development Corporation, for permission to publish this paper.

DISCUSSION

(*Eugene A. Stephenson presiding*)

H. H. Power,* Tulsa, Okla.—Is it true, Mr. Kemler, that you can take a dynamometer card, and, from your studies find the irregularities in that card, and perhaps interpret them to better advantage by knowing the various influences in the system and their relation to each other?

E. Kemler.—We have not gone that far as yet. You can, for example, find out what effect a lot of gas in the tubing would have on the rod loads by simply increasing the size of the condensers in the circuit representing the oil column. It is possible to study one at a time—the factors entering into the problem. I do not know that it would be desirable even to try to take a dynamometer card and work it backwards, because of the electrical difficulties involved.

H. H. Power.—Are not some cards hard to interpret, just looking at them offhand? For instance, you showed one card with a high peak at the beginning, then a drop, with the main stress at the middle of the stroke. It seems to me that studies of this sort would enable us to interpret these cards better.

I think perhaps that we take too many cards in the field that are not properly interpreted. We say that we get so much polish-rod horsepower. We have a high peak load. Our minimum is so much and so on, but we do not get down to the fundamental characteristics of the various parts of the stroke. For instance, if it is delayed valve action that causes an irregularity at the beginning of the stroke, maybe that could be cured by proper changes, or perhaps we could identify harmonic vibrations and change operating cycles to effect the best results.

I am interested in this study, particularly from the standpoint of analyzing the cards to better advantage. It seems to me that it should eventually point to a real application of that sort.

E. Kemler.—I think that is possible. For instance, in such an operation as anchoring the tubing, all that is necessary is to throw a switch and shunt out part of the electrical circuit, and see what effect that has on the card. If you want to see what effect the rubber shock absorber or any other kind of shock absorber would have on a

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* Chief Production Engineer, Production Department, Gypsy Oil Co.

system, you put in a condenser at the top of the rod circuit. By varying that condenser, for instance, you could see what effect different size and design of shock absorbers would have on the system, so that in part the method does permit the study of the individual factors, which when put together would help in interpreting the cards

D. G. KINGMAN,* Los Angeles, Calif. (written discussion).—This paper shows detailed study in the development of a new method of attacking the problem of determining the occurrences at the bottom of a pumping well. Although the actual well conditions that can be simulated by the model are limited, considerable of value in a general way can be learned about the load and travel at the bottom of the rod string as affected by conditions at the top.

When the magnitude of all the variables affecting a well are known, it should be possible to reproduce the well in the model. Unfortunately, all the variables in a well are not known and are not likely to become known, thus precluding the possibility of reproducing a particular well in the model unless assumptions are made that would tend to invalidate the results. There is, however, a possibility that a well could be reproduced in the model by first reproducing the known factors and then varying the unknown ones until the card obtained with the oscillograph is the same as that secured with the polish-rod dynamometer. There would then be a probability that below-ground conditions in the model were similar to those existing in the well.

H. N. MARSH,* Los Angeles, Calif.—Dr. Kemler deserves unstinted praise for the successful carrying out and reporting of an interesting and difficult research. Both the mechanical model and electrical analogy methods have dismayed by their complexity those who have previously considered them.

Use of the equations and apparatus necessarily assume, among other things, the amount of friction; that this friction is distributed uniformly from top to bottom of the well with none concentrated at the plunger; and that it is proportional to the first power of velocity. Further, the pump is assumed to have no material submergence, but to have 100 per cent volumetric efficiency—factors that it is important to determine rather than to assume.

It is not clear as to what, if any, specifically useful data can be procured with the electrical apparatus that cannot be determined more directly and positively by using the ordinary dynamometer on an actual well. Of course, it permits predicting performance of a well that is not yet pumping, but such predictions must be based upon so many questionable assumptions that it would appear more satisfactory to rely even for this purpose upon a dynamometer test of a similar well.

Regardless of whether specifically useful data can be produced by the electrical apparatus, study of this paper, together with additional illustrative data, will result in an improved qualitative understanding of the sucker-rod problem.

E. KEMLER.—I do not think the method ever will be applicable to a specific well. Some progress can be made by studying each factor at a time, and perhaps some day some one will be able to go ahead and study the specific wells.

The question of plunger motion is rather interesting. This analogy, as applied to a sucker-rod system, is identical with a long transmission line. If, for instance, there were just the sucker rod with the pump on the bottom and no fluid was being pumped, it could be shown that at the speed normally used the plunger motion would in every case be greater than the polish-rod motion.

* General Petroleum Corporation of California.

Laboratory Investigations on Acid Treatment of Oil Sands

By F. B. Plummer,* Member A.I.M.E. and R. B. Newcome, Jr.†

(Houston Meeting, October, 1935)

The practice of introducing acid into oil wells to increase production of oil and gas has been in use since 1894, when it was first used in the Pennsylvania oil fields[30].‡ It is only since 1928 that it has been used to any extent in the Mid-Continent[18]. The process has proved successful in increasing production, at least temporarily, in depleted oil fields where the producing formation is highly calcareous and where water drive is not too pronounced. In the Zwolle field in Louisiana, where the producing horizon is a chalk, increases of 100 per cent have been recorded[25]. In north-central Texas, where the oil is produced from the Marble Falls limestone, equally pronounced increases have resulted[3]. The production also in some fields yielding oil from quartz sand cemented with calcite has been benefited. The evidence of actual increase in total recovery of oil, however, has been questioned by some engineers[18]. It has been pointed out that the results of the treatment of a well in a new district, where the process has never been tried out, can never be predicted with certainty, since other factors besides percentage of calcareous content of the oil sand play a large part in determining the success of the method.

Numerous articles have been published on acid treatment and on the effects of acid on limestone[1–35], yet very little has been written concerning experimental work on the actual effect of acid on capillary pores and larger oil-coated voids of oil sands. This is due partly to difficulties in duplicating field conditions in a laboratory and partly to the fact that the process has been carried out largely by contracting companies that have been unwilling to publish details of their results for fear of loss of business to competitors. The authors, using equipment developed to measure the radial permeability of oil-sand cores[29], have developed a method of investigating the results of acid treatment which has enabled them to test numerous cores and to study in some detail the action of acid on the different types of rocks, particularly fine-grained rocks.

Manuscript received at the office of the Institute July 30, 1935.

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† Instructor, Department of Petroleum Engineering, University of Texas.

‡ References are at the end of the paper.

These results, although somewhat at variance with the usual conception of the effect of acid treatment on oil sands, are thought to be of sufficient interest to be worth describing.

Method of Investigation and Apparatus Used

The method employed to test the effect of acid treatment on a core of oil sand consists of cutting a 4-in. core of the formation with a special core cutter, drilling a ¾-in. hole lengthwise through its center, placing the core in the radial-permeability apparatus (Fig. 1) and measuring accurately the rate of flow of kerosene through the core at measured pressures. The core is then treated with acid, and its permeability is again measured under exactly similar conditions. In these tests the acid treatment was repeated several times with different strengths and amounts of acid, and the different rates of acid penetration and the permeability were again measured. The results were calculated in darcys by Muskat's formula[27], and were checked, compared, and plotted in the form of graphs.

Fig. 1.—Radial permeability apparatus used in experiments on acid treatment.

The apparatus for measuring the rate of flow is similar to the multiple-permeability apparatus described by Plummer, Harris, and Pedigo[29], with the following modifications:

The receiving flasks *F* (Fig. 2) are of new design and are manifolded through stopcocks to a 1½-in. inclined brass pipe *A*. The upper end of the pipe is connected with a ¼-in. brass tube *B*, attached to the compressed-air supply. The lower end of the pipe has a similar tube *C*, extending into a 5-gal. receiving bottle *D*, and another tube *G* at its lower end, which serves as a drain. The upper end of the inclined brass pipe has also a ¼-in. standpipe *E*, rising above the level of the top of the receiver. One other ¼-in. pipe *H* is attached by means of a T-tube *K* at the lower end of manifold *A*. Pipe *H* is not in use during permeability measurements, but when acid is run into the core it is attached directly to the well-head flow pipe and serves to convey acid from the receiving pipe *A* into the well head and thence into the core without removing the core from its holder (Fig. 3).

All tubes attached to the manifold pipe A are fitted with gate valves, as shown in Fig. 2. These valves allow the liquid flowing from the oil

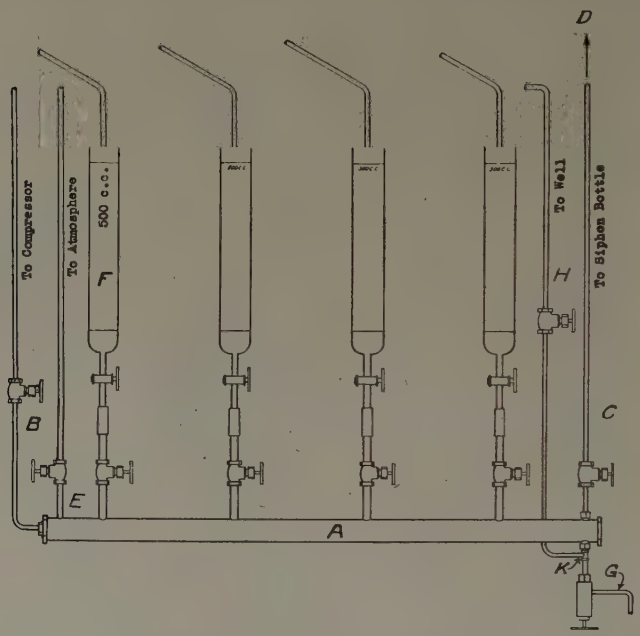


FIG. 2.—HOOK-UP OF RECEIVING FLASKS AND MANIFOLD USED IN MEASURING PERMEABILITY OF LIMESTONE CORES.

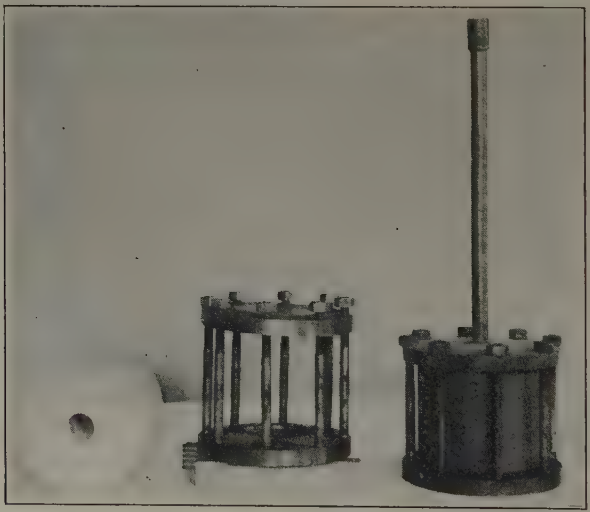


FIG. 3.—CORE AND CORE HOLDER BEFORE ACID TREATMENT.

reservoir to be measured in the receiving flasks, delivered into pipe A, and then blown into the receiving bottle D, from which the fluid may be

siphoned back through the brass siphon tube E into the lubricator L (Fig. 4), and then delivered into the pan of liquid containing the cores (Fig. 1).

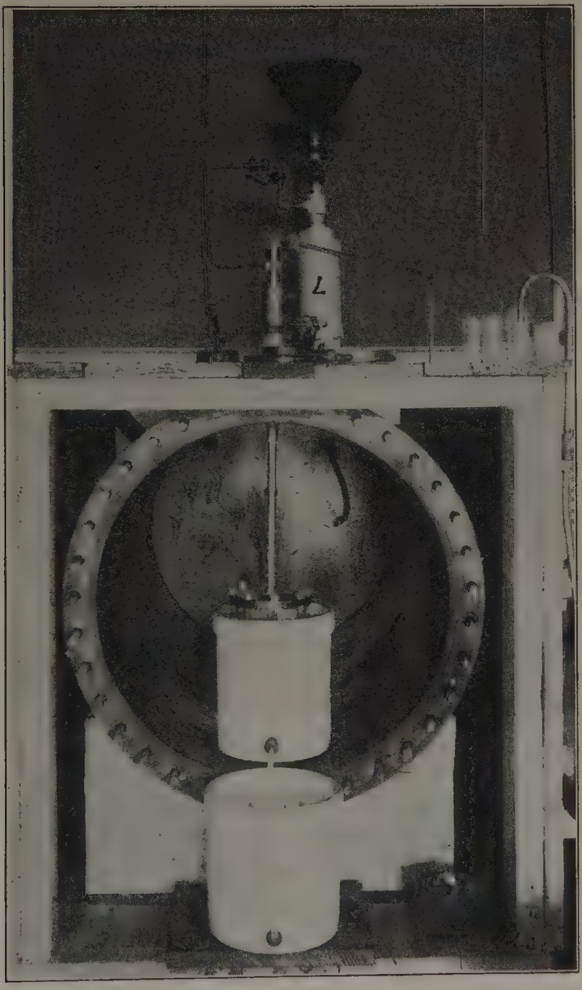


FIG. 4.—LIMESTONE CORES INSERTED IN CORE HOLDERS HOOKED UP TO RECEIVE ACID.

By manipulating another set of valves, the liquid can be forced at any desired pressure up through pipe H (Fig. 5) into the well head W, and thence down into the center of the core, which corresponds to a well bore. The fluid can be forced through the core into the reservoir when it is desired to treat the core with acid, or it can be flushed back between tubing N and casing P into tube I (Fig. 5), when it is desired to wash out the interior of the core.

Description of Experiments

Slow Acid Treatment of Cores with Capillary Forces Predominating. Cores of the following typical fine-grained reservoir rocks were prepared as described above and placed in the core holders:

Sample No. 1. Spherulitic limestone of Georgetown age (Lower Cretaceous) from outcrop in Travis County.

Sample No. 2. Austin chalk (Upper Cretaceous) from outcrop in Travis County.

Sample No. 3. Leuders limestone (Permian) from outcrop at Leuders.

Sample No. 4. Strawn sand (Pennsylvanian) from outcrop in Palo Pinto County.

The cores were placed in the core holders, their ends smeared with Dart cement and tightly clamped in place between the thick rubber gaskets of the holders (Fig. 3). Outlets of glass Wolff bottles containing 250 c.c. of 50 per cent commercial hydrochloric acid (sp. gr. 1.07) were connected by glass tubes with the upper ends of the core holders. The acid was then allowed to run into the center of the core, to percolate slowly through the sand, displacing the liquid in the core outwardly and attacking the calcium carbonate. The spent liquor resulting from this reaction was delivered into the receiving jars *R*, below (Fig. 5). The flow of acid is very slow, requiring about 48 hr. for 250 c.c. to flow through samples Nos. 1 to 3, and about 12 hr. to flow through more permeable calcareous sandstone core (sample No. 4). As soon as the acid treatment was completed, the cores were washed with distilled water, replaced in the permeability apparatus, and immersed in kerosene. Air pressure was then applied to the cylinder so that the liquid was forced back through for several hours, until all trace of acid or water was removed. The permeability of the cores was measured as described by Plummer, Harris and Pedigo[29]. The results are shown in curves *A* and *B* in Figs. 6, 7, 8 and 9, and in Table 1. The decrease in permeability ranges from 4 per cent in the Strawn sandstone to 62 per cent in the Austin chalk. The increase in size of the holes corresponding to the well bore ranges from zero in the Strawn sandstone to 5 per cent in the Leuders limestone.

Treatment under Medium Pressure.—Cores 1, 2 and 3 were then replaced in the core holders. Another core of the Strawn sandstone, No. 4*a*, was substituted for core No. 4. The permeability of the new core, No. 4*a*, had already been measured (curve *C*, Fig. 10). The cores and holders were then inserted in the pressure cylinder, and the well heads were connected up with the flasks containing 250 ml. of the acid (Fig. 5). The cores were then treated with 250 c.c. of 50 per cent commercial HCl (sp. gr. 1.07) under a pressure of 25 lb. per sq. in. The acid was delivered through the cores at rates ranging from about 12 min.

for the Strawn sandstone core to about 10 hr. for the Austin chalk core. The spent acid delivered into the jars (Fig. 5) showed no acid reaction with litmus. The cores were thoroughly flushed out with distilled water and washed in kerosene. The jars were then removed, kerosene introduced into the pressure cylinder, and the permeability again measured. The results of the treatment are shown in the curve *C* in Figs. 6 to 9 and in

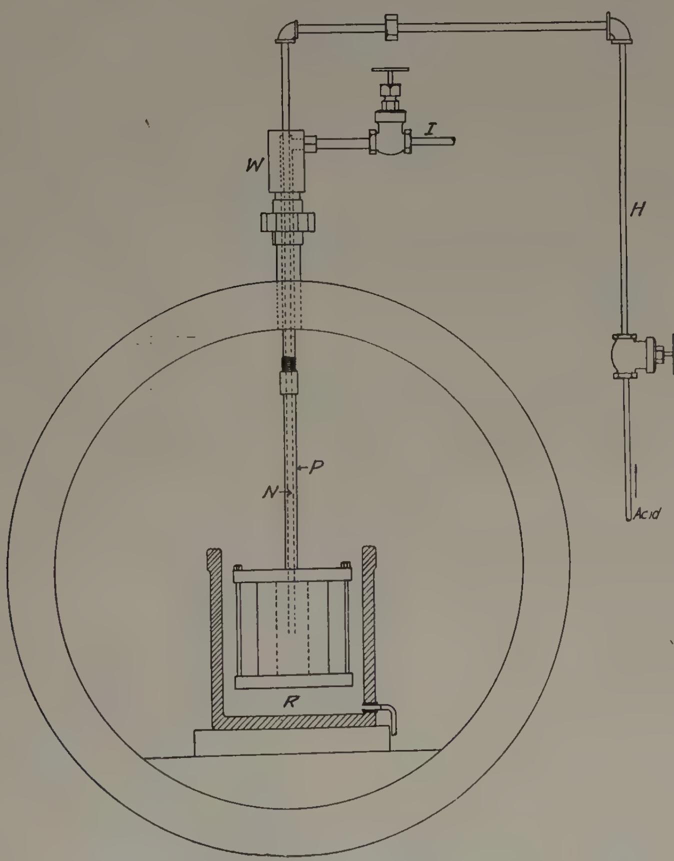


FIG. 5.—HOOK-UP USED IN SLOW TREATMENT OF CORES WITH ACID.

Table 1. The decrease in permeability this time ranged from 19 per cent for the Leuders limestone to 74.7 per cent for the Georgetown limestone, and the increase in the size of the holes (well bores) in the cores ranged from zero in the Strawn sand to 46 per cent over the original hole size in the Georgetown limestone.

Treatment under Higher Pressure.—The same cores were then treated again in exactly the same way with 500 c.c. of the HCl under pressure of 50 lb. per sq. in. for a period of 5 min. for the Strawn sandstone and for

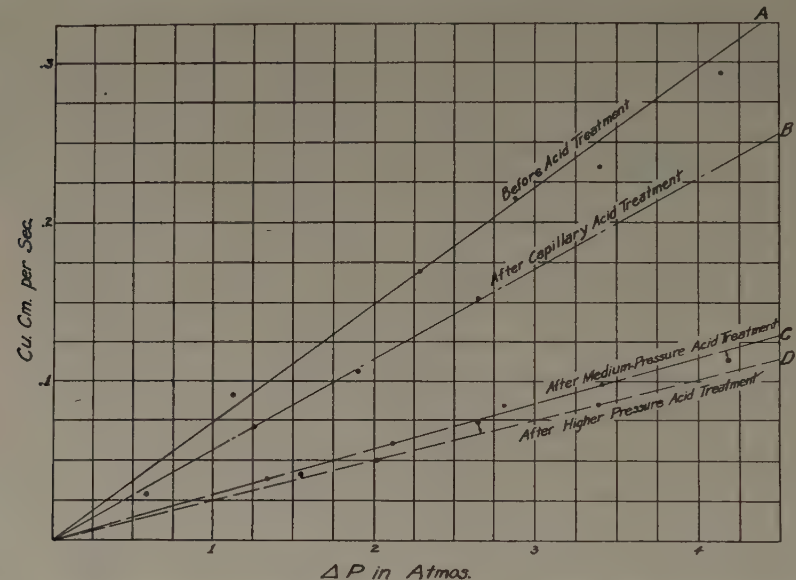


FIG. 6.—RESULTS OF ACID TREATMENT OF CORE NO. 1, LOWER CRETACEOUS (GEORGETOWN) LIMESTONE.

Solid line indicates permeability before acid treatment; broken lines, permeability after acid treatment.

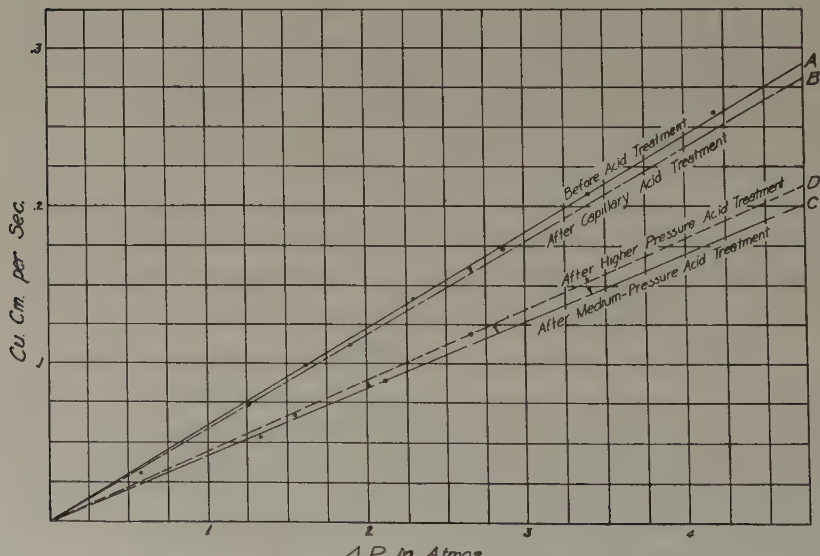


FIG. 7.—RESULTS OF ACID TREATMENT OF CORE NO. 2, UPPER CRETACEOUS (AUSTIN) CHALK.

Solid line indicates permeability before acid treatment; broken lines, permeability after acid treatment.

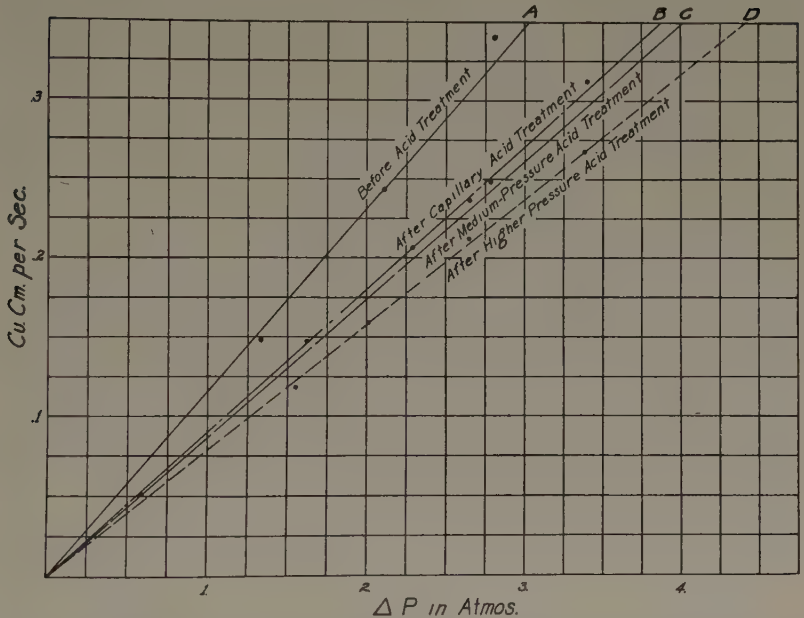


FIG. 8.—RESULTS OF ACID TREATMENT OF CORE No. 3, PERMIAN (LEUDERS) LIMESTONE.
Solid line indicates permeability before acid treatment; broken lines, permeability after acid treatment.

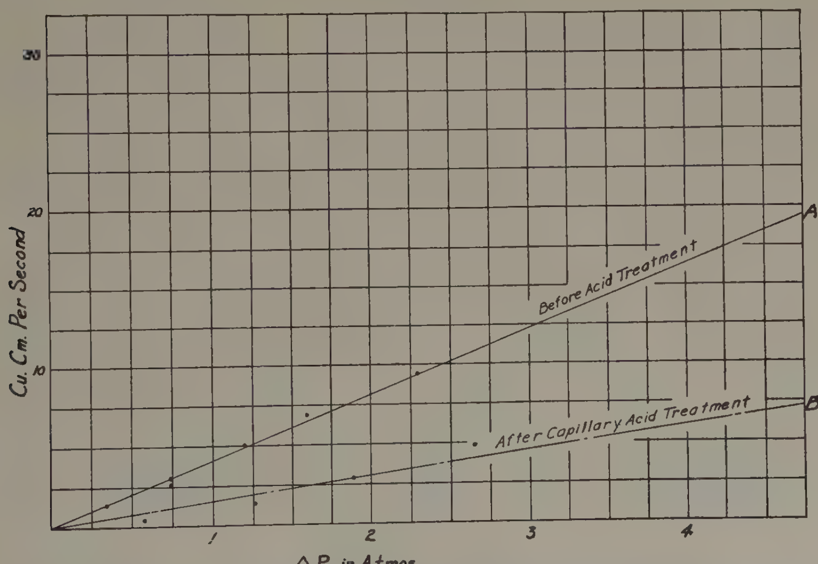


FIG. 9.—RESULTS OF ACID TREATMENT OF CORE No. 4, PENNSYLVANIAN (STRAWN) SANDSTONE.
Solid line indicates permeability before acid treatment; broken lines, permeability after acid treatment.

about 20 hr. for the Austin chalk. The liquid delivered through the cores into the jars was neutral to litmus, except that from the Strawn sandstone.

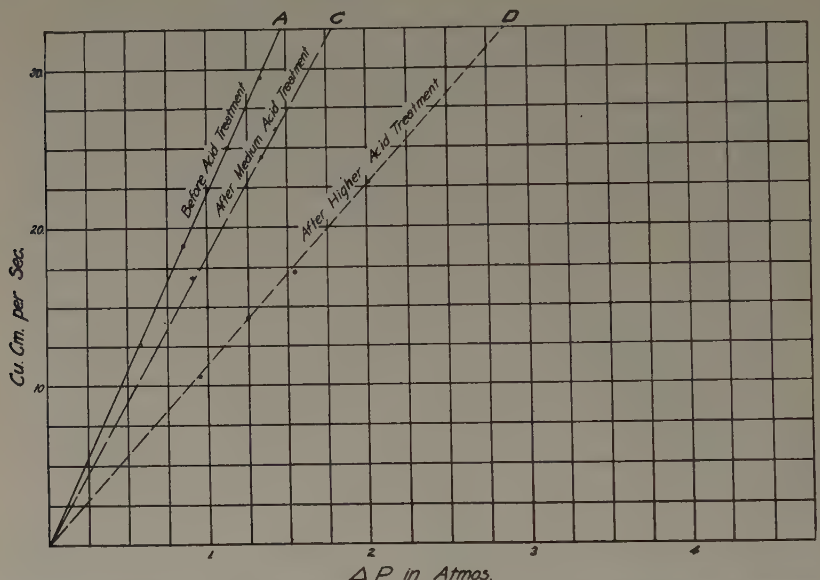


FIG. 10.—RESULTS OF ACID TREATMENT OF CORE NO. 4A, PENNSYLVANIAN (STRAWN) SANDSTONE.

Solid line indicates permeability before acid treatment; broken lines, permeability after acid treatment.

The liquid came rapidly through the porous Strawn sandstone core and issued in the form of a spray of partially spent acid. The cores were then washed thoroughly with distilled water, and the permeability was again measured. The results of this final treatment are shown in curves

TABLE 1.—*Summary of Results of Acid Treatment*

Core No.	K[a] before Acid Treatment	K after Acid Treatment No. 1[c]	Loss in K from Treatment 1, Per Cent	Gain in Bore Size in Treatment 1, Per Cent	K after Treatment No. 2[c]	Loss in K from Treatment 2, Per Cent	Gain in Bore Size in Treatment 2, Per Cent	K after Treatment No. 3[c]	Loss in K from Treatment 3, Per Cent	Gain in Bore Size in Treatment 3, Per Cent
1	0.002890	0.002300	20.4	4.3	0.000730	74.7	46.2	0.000522	81.9	86.1
2	0.002760	0.002640	4.3	2.0	0.001150	59.3	41.3	0.000940	65.9	85.8
3	0.003980	0.003755	5.2	5.3	0.003208	19.4	35.0	0.001800	54.8	64.6
4	0.2175	0.0812	62.7	0.0						
4a[b]	0.7040				0.5470	22.3	00.0	0.3630	49.8	0.0

[a] K represents the permeability in darcys.

[b] Core No. 4 was replaced by core No. 4*a* after treatment by capillary method.

[c] 1, slow capillary treatment; 2, medium pressure acid treatment; 3, higher pressure, rapid acid treatment.

D in Figs. 6, 7, 8 and 10 and in Table 1. The decrease in permeability ranged from 50 per cent from its original permeability for the Strawn sandstone to 82 per cent of the original for the Georgetown limestone. The change in size of the holes in the cores ranged from zero in the Strawn sandstone to 86 per cent increase over original hole size in the Georgetown limestone (Fig. 10).

Discussion of Experiments

The results of the experiments show clearly that acid treatment of fine-grained cores results in a large loss in permeability. This loss appears to be due to clogging of pores by very fine and insoluble residues, which under the microscope show fine, needlelike crystals of acid-insoluble silicates mixed with a little colloidal silica and traces of colloidal organic matter. In cores in which the interspaces are less than 0.01 mm. in diameter, the insoluble residue resulting from the solution of limestone clogs up the pores and definitely lessens the flow of liquids through them. Samples of the cores were dissolved in dilute C.P. HCl, with the following results:

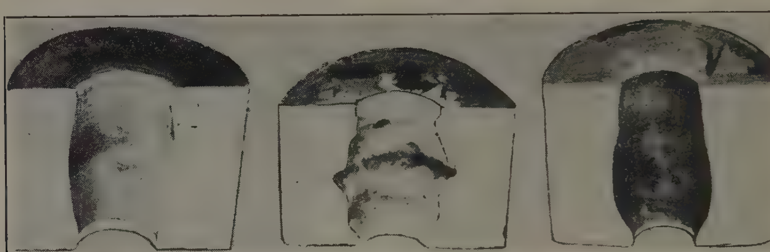
	Percentage of Insoluble Residue[a]		
	Sample 1	Sample 2	Average
Core No. 1 (Georgetown)	0.235	0.233	0.234
Core No. 2 (Austin)	7.180	6.059	6.619
Core No. 3 (Leuders)	0.870	0.976	0.923

[a] Analyzed by A. S. Trube.

The effect of this insoluble colloidal and crystalloidal material on the permeability varies with the texture of the porous rock. In rocks in which the pores are very large and the fluids travel chiefly through the larger channels, as in the large cavities of Bend limestone of north-central Texas and in the cavernous Cretaceous limestones of the south part of the Golden Lane field of Mexico, and in the highly porous Permian limestones of Winkler County, Texas, and southeastern New Mexico, the acid is forced rapidly into the channels and enlarges the existing passageways. Any residue left by the acid reaction can be washed out through the channels, if the wells are swabbed or pumped rapidly after treatment. In fine-grained rocks, the penetration of the acid even under the higher pressures is slow. The acid becomes spent before it has traveled far into the formation. The chief result of the treatment is to enlarge the diameter of the bore hole (Fig. 11). At the same time any colloidal matter in the spent acid is forced on into the fine interspaces in the rock, which results in clogging and lowered permeability. *Ordi-*

nary acid treatment of very fine-grained rocks may be harmful rather than beneficial.

It has been suggested by some engineers that in treating coarse-grained, partly cavernous rocks, better results might be obtained by forcing a soluble gelatinous substance into the larger cavities before treating. They suggest that the soluble gel should keep the acid out of the larger cavities and permit it to be forced into the small spaces where it would do most good. After the acid treatment is over, the gel, of course, would be dissolved out by a suitable solvent. It would appear from the results of these laboratory experiments, however, that such a procedure might not be successful. If the fine capillary spaces are clogged by colloidal matter produced by the acid, the permeability would be lowered;



A *B* *C*

FIG. 11.—SECTION OF CORES AFTER TREATMENT, SHOWING ENLARGEMENT OF BORE HOLES BY ACID TREATMENT.

and if the larger fluid passageways are not enlarged, the result would be a smaller production of oil.

It is probable that some form of liquid treatment other than acid may prove beneficial to some fine-grained oil sands. It is evident that the fine pores in limestones may become clogged with paraffin and other organic matter after the well has produced for some time, and production greatly reduced. It is known that if organic solvents of low surface tension and low viscosity, like benzene or high-test gasoline, are forced under pressure into the fine pores of partly clogged sands, then swabbed out, increased permeability will result. Tests made in our laboratory have shown that even traces of paraffin dissolved in kerosene markedly reduce the permeability of these fine-grained cores. In one test the reduction in permeability was as much as 75 per cent. The paraffin, however, was easily removed, and the permeability was restored by washing with benzene.*

It appears, therefore, that the method of treating each well is a separate problem. The kind of rock, the texture of the oil sands and the

* Experiments are now being carried out in our laboratory to study the efficiency of different organic solvents in increasing the permeability of paraffin-clogged, fine-grained oil sands.

nature of the oil are important characters that may affect markedly the success of an acid program. These factors and others should be considered, and certain preliminary tests should be made to determine their affect on the flow of oil, before the final method of treatment is decided upon.

To sum up, the important results of these experiments are in showing that, if the limestone is fine grained and impure, as are many oil-reservoir rocks, the insoluble residue dissolved from the core by the acid is in granules and minute acicular crystals larger than the pore spaces in the rocks. Therefore this material clogs the core and decreases permeability, no matter how much washing or swabbing is done in an endeavor to clean it.

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DISCUSSION

(*T. V. Moore presiding*)

W. V. Howard,* Urbana, Ill. (written discussion).—In confirmation of some of the results of Plummer and Newcome, I wish to say that in the treatment of several thousand samples of limestone by the centrifuge method[36], we have found that the swelling of insoluble residues in the presence of HCl is the rule, rather than the exception. Sometimes, after vigorous effervescence in our light fraction (indicating the presence of a considerable quantity of calcite) we have found the volume of the insoluble residue to be from 120 to 200 per cent of the original fraction. In some limestones the insoluble residues swell from four to six times their original volume.

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[36] C. B. Claypool and W. V. Howard: Method of Examining Calcareous Well Cuttings. *Bull.* Amer. Assn. Petr. Geol. (1928) **12,** 1147–1152.

At other times, when we simply immersed cores in HCl in order to determine the nature of the residue and of the type of porosity developed, we found that the residue contained carbonate. The acid ripped off grains of carbonate, possibly aided by the swelling of the residue, and these grains were not dissolved before the acid was spent.

Naturally, if any attempt is made to force these residues or carbonate grains through a fine-grained limestone, a decrease in permeability will follow. Also, it follows that the more the swelling, the greater the decrease in permeability.

It is difficult, however, to see in what way these results can be applied to the acid treatment of oil wells. This does not involve forcing spent acid and residues through dense limestone. It does not even involve dissolving the reservoir rock, except in so far as this cannot be prevented. In fact, any acid that dissolves the reservoir rock is wasted.

The fact that a given reservoir is limestone is of great importance in the formation of that reservoir. Different types of limestone give rise to different types of porosity. Once this porosity is developed and the rock becomes a reservoir, further solution of any portion of the wall rock will be followed by precipitation of calcium carbonate elsewhere and this may easily reduce permeability. Thus, once porosity has been developed and oil has entered the reservoir, it is much better to have an insoluble reservoir rock than a soluble one.

The porosity of a reservoir may be considered to be at a maximum at the time that oil enters it, or is formed in it. It is true that there may be later solution, but there is also certain to be subsequent deposition of calcite, which will tend to clog up openings through which oil might reach wells. The deposition of secondary calcite takes place first, when CO_2 resulting from reactions within the reservoir combines with calcium ions in solution, and, second, when calcium carbonate is precipitated in the reservoir near the well, as a result of the drop in pressure due to production.

Acid will clean out this later precipitate and, if it can be forced along channels without dissolving the walls of those channels, it will remove some of the earlier generation of secondary calcite and may bring new productive areas into the area drained by the well. In both cases, the acid is, or should be, engaged in permeability restoration.

If merely dissolving the reservoir were the main function of the acid treatment, about 1000 lb. of acid dumped into a 6-in. hole through a 30-ft. lime pay would double the area of the face exposed. If the reservoir were a uniformly porous rock and the oil were moving along the openings to the well, doubling the surface exposed would double the production of the well. Yet this method of acid treatment has not been seriously advocated, because there is a great deal of evidence to the effect that movement of oil through limestone reservoirs is along fairly well defined channels. Acid treatment should be directed towards clearing out and extending these channels.

Experimental work on limestone cores will tell relatively little concerning production from limestone until we are able to obtain cores with the same degree of differential permeability that we find in the ground. On the other hand, experimental work on limestone cores will tell us a great deal about the type of porosity that may be found in them, and about the behavior of the residue upon acid treatment. Knowing whether or not the residue will swell would aid the acid-treating companies in choosing the proper chemicals to add to their acid to overcome this difficulty in part at least.

J. J. Grebe,* Midland, Mich. (written discussion).—The paper serves to illustrate clearly the many pitfalls that exist in a laboratory approach to the study of acid treatments of wells. It further indicates how actual well treatments can be carried out improperly. These points were recognized and implied by the authors in their introduction.

* Physicist, The Dow Chemical Co.

The differences between the adverse results obtained by the authors and the very favorable results that have been obtained in the field are largely due to the following:

1. The acid, defined as "50 per cent commercial hydrochloric acid (sp. gr. 1.07)," actually 15 per cent HCl by weight, contained no inhibitor. It is certain that enough of the brass tubing was dissolved to leave a considerable amount of heavy metal hydroxide in the pores where the acid was finally neutralized.

In addition, many commercial acids cannot be used satisfactorily because they contain impurities that would form precipitates with some components in the formation.

2. The core samples were small, relatively uniform, portions from an outcrop of the pay formations. They were not representative of an actual formation with its channels, crevices, bedding planes and irregular porosity. They precluded the possibility of the acid opening up channels and removing the plugging agents; instead the rock sample was uniformly attacked.

3. Much of the acid was spent in the borehole and its immediate vicinity. It is obvious, then, that residues of the disintegrated rock together with precipitates of impurities in the acid were carried into the pores. On top of this, any of these impurities that reach the outer portions of the core are cemented in place by the $CaCO_3$ precipitated as a result of the liberation of CO_2 from the dissolved bicarbonate. This is well demonstrated by the fact that the higher the pressure used, the more plugging occurred.

In actual field tests it has been found that under good conditions of treatment, 12,000 gal. of acid introduced into a single well did not increase the diameter of the bore to any measurable extent but ate "wormholes" into the porous rock, the face of which still showed original tool marks when portions of it were shot out.

4. Backwashing was done with neutral water and kerosene, not as it should have been done with CO_2-saturated, slightly acidic, products of the reaction. Furthermore, it is very likely that between the CO_2, water, and kerosene there was produced an appreciable amount of "Jamin effect" or "bubble plugging effect" due to interfacial tension, which would reduce the permeability as measured.

When treating actual wells under similar conditions of very fine porosity and extremely low rock pressure, an acid composition of low surface tension, as described by L. C. Chamberlain in Patent No. 2024718, Dec. 17, 1935, should be used.

5. It is questionable whether the method used for measuring the permeability is satisfactory, even if the above points of treating technique were corrected.

Attention is called to the following publications: Charles Nevin: Permeability—Its Measurement and Value. *Bull.* Amer. Assn. Petr. Geol. (April 1932); and, in the same bulletin, for February, 1934, Wyckoff, Botset, Muskat and Reed: Measurement of Permeability of Porous Media.

W. E. Winn,* Dallas, Tex.—In correlating our laboratory tests with results in the field, we have found that if the average acid-soluble content of a formation is less than 70 per cent, the results of acid-treating the wells are not very good; if above 70 per cent, the results are good.

We also found, by comparative tests, that the corrosion of seamless tubing by the acid was less than with lapwelded tubing and that an oil film delayed the acid action for several hours.

In a further series of tests we found that acid could be used to open perforations in cement where the bullets had failed to completely penetrate the cement.

R. Van A. Mills,† Ponca City, Okla., briefly reviewed the possibilities of obtaining better results with acid by increasing the generation of gas in the producing formations,

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especially in sand formations. This he proposed to do by injecting into the formations alternate slugs of hydrochloric acid and solutions of sodium carbonate, interspersed with slugs of oil to keep the reagents separated until they penetrate the producing formations.

Experiments in sand formations by this method are in progress. It is anticipated that the sudden effervescence and creation of gas pressure in the presence of an excess of acid over that required to react with the carbonate solution will assist materially in cleaning out the pores of a sand, provided the reactions take place in the formations themselves at short distances from the wells.

Investigations on the Recovery of Oil from Sandstones by Gas Drive

By Gerald L. Hassler,* Raymond R. Rice† and Erwin H. Leeman†

(New York Meeting, February, 1936)

In the past few years a great deal of precise information has been obtained about the relation of natural gas to oil production[1]. The improvement of our understanding has been of great value, both in prolonging the life of wells and in providing a much needed technical background for the legal problem of proration. But there are two principal aspects of the problem of production. It is necessary to consider not only the energy available, in the form of compressed and dissolved gas and in the pressure of driving water, but also the tenacity with which the sandstone holds the oil. The amount of oil that each sand condition will produce under given conditions of gas content should be determined. Hitherto the effect of the sand has been judged by a study of the flow of each well coupled with a procedure for extrapolating the production curve; but, as is well known to evaluation engineers, such production curves are subject to changes that are not well understood, and often are affected by outside disturbances.

On the whole, the concept of "potential production" is vague principally because the influence of the sand in production is not known beyond the simple ideas of porosity and permeability. The permeability is a quantity that has only inference value where mixtures of gas and oil or of gas, oil and water are present.

Excellent studies of the production of oil from reservoirs packed with unconsolidated sand are available[2], but these studies treat largely of *small-scale analogies* to a producing field, and the conclusions to be derived from them are necessarily of a qualitative character because it is not known in what way these miniature oil fields resemble large ones.

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† National Youth Administration student assistant.

[1] See, for example, the series of articles by W. N. Lacey and collaborators: Phase Equilibrium in Hydrocarbon Systems. *Jnl. Ind. & Eng. Chem.* (1934, 1935, 1936).

[2] H. H. Power: *Trans.* A.I.M.E. (1928–29) **82,** Petr. Dev. and Tech., 313.

Uren, Domercq and Meija: *Trans.* A.I.M.E. (1935) **114,** 25; *Oil & Gas Jnl.* (Sept. 5, 1935) 40.

L. C. Uren: *Trans.* A.I.M.E. (1928) **77,** Petr. Dev. and Tech. in 1927, 146.

The experiments described in this paper were planned with a view to the discovery and measurement of elementary quantities that may be useful in setting up the differential equations that describe the flow of oil and gas through sandstones. Thus, in the theory of flow of heat the thermal conductivity, specific heat, emissivity and temperature are used in certain differential equations, which need only the boundary conditions of any specific problem to solve the problem of heat flow of that situation. The porosity and permeability are two such quantities in the corresponding problem of oil production. But the permeability for *all saturations* encountered in practice must be known, not simply the "dry" permeability. If a law could be found relating the rate of transfer of oil through sandstone to some property that may be called, for the present, an "oil transfer coefficient," it would be possible, given the saturation and rate of flow of gas through the sandstone, to calculate the rate of movement of oil. Another possible constant of oil production, measurable for each sandstone, or perhaps expressible in terms of other physical properties, is the ratio of the volume of gas that comes out of solution in the oil contained in a sandstone to the volume of oil that is thereby forced out of the stone. This has been measured for tanks and pipes of various forms filled with unconsolidated sand, but it is suggested that there exists a quantity that is independent of the boundary or size of sample, corresponding to the "divergence" of potential theory.

Such an attempt to work out the experimental basis of a general theory of oil production is ambitious in view of the complexities involved; perhaps these general equations could not be solved even if they could be set up. But experiments that are designed to eliminate the effect of boundaries and form of the apparatus will be instructive, just as the oil-field analogies are, even though the complete equations are not obtained. The authors have witnessed and had a part in an astonishing growth of graphical and numerical computation in the field of torsion balance and magnetometer interpretation, which leads them to believe that the mathematical difficulties appear insuperable only at a distance. Once the problem of oil production is well defined, the mathematicians will not be long in solving it and reducing the solution to a usable form.

Apparatus, Materials and Procedure

Six cylindrical samples of sandstone were chosen from the Pennsylvania Core Depository. All were fine grained and of the Bradford sand type, obtained from Cattaraugus County, New York. Their properties are given in Table 1.

The cores were chosen with special reference to absolute uniformity of appearance. The fluid in each of these cores was subjected to a regulated air pressure of 40 lb. per sq. in. The oils used in saturating the cores were

prepared by mixing kerosene with a white paraffin oil The physical properties of the mixtures are shown in Table 2.

TABLE 1.—*Properties of Sandstone Samples*

Symbol[a]	Laboratory No.	Permeability, Millidarcies	Porosity, Per Cent	Diameter, Cm.	Length, Cm.
Upright cross	A786	8.3	0.095	1.96	2.40
Square	B78	10.4	0.149	1.96	2.57
Circle	B68	14.5	0.153	1.96	2.41
Triangle	A544	15.9	0.157	1.96	2.34
Parenthesis	B66	20.7	0.164	1.96	2.41
Crossed circle	B28	31.4	0.170	1.96	2.31

[a] This column gives the reference mark used in the plotted points of that sample.

TABLE 2.—*Physical Properties of Saturating Oils*

Symbol	Kerosene, Per Cent	Density	Viscosity, Centipoises	Surface Tension, Dynes
A	0	0.880	66.0	32.1
B	20	0.861	20.8	31.0
C	40	0.846	8.66	30.5
D	60	0.831	4.38	29.6

The test specimens were saturated by evacuating for an hour at pressures less than one millimeter of mercury, flowing in enough oil to cover them while still evacuated, and soaking overnight at atmospheric pressure. The degree of saturation obtained in this way was ascertained by measuring before each experiment the dry weight of the core, the density of the oil (after evacuation and standing), and the pore volume of the core (in Washburn-Bunting apparatus). The saturation is defined as the ratio of volume of oil to pore volume.

The saturated core was placed in its holder (to be described below), the time was noted and the pressure turned on. After a suitable measured interval of time the drive pressure was shut off, the core was removed, taken to a chemical balance for weighing, and returned immediately to the action of air drive in the apparatus. The time intervals were chosen so as to permit a measurable change of saturation to take place, and was as great as 24 hr. in some instances. The core was always returned to the same orientation, so that the oil was driven in one direction only. As often as convenient, measurements of the rate of flow of the driving air were obtained with either a capillary resistance flow meter or a wet test meter placed after the core specimen. Thus the saturation of the core was followed by weight difference and the air flow was determined by direct measurement of either volume of air or drop in pressure past an obstacle to flow.

The core holder (Fig. 1) is the heart of this apparatus, and upon its quick action depends the success of this weight-difference method of following the saturation. In it the core is surrounded by a thin-walled rubber tubing *A*, of the kind used for Gooch crucibles. This tube is pressed against the cylindrical boundary of the test core *B* by applying air pressure to the chamber *C* considerably greater than the greatest pressure of the driving air within the core. A Bourdon tube gage is used to measure this sealing pressure, and throughout these experiments it was kept in the neighborhood of 50 lb. per sq. in. greater than the greatest inside pressure. By connecting the space *C* outside to an aspirator pump, sufficient vacuum is obtained to suck the rubber tube *A* away from the core. Since it is mounted vertically, the core will drop out into the hand of the operator as soon as the vacuum valve is turned. The operation of removing the core, weighing it and replacing it can be done readily in five minutes. The loss in weight during this operation averaged, for oil C, about 0.0003 gram.

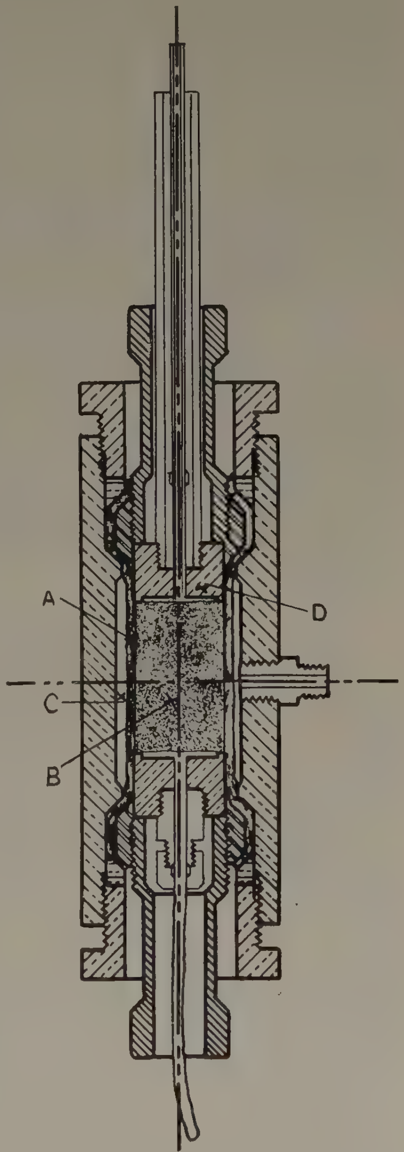

Fig. 1.—Section of core holder. Two kinds of end fittings are shown, one (below) with a compression fitting to take ⅛-in. copper tubing, the other with a soldered connection and a ¼-in. pipe section screwed into the end plug *D*. This pipe can be used to push out the core forcibly when necessary.

The brass end plugs *D* generally fit the fractured ends of the sandstone sample well enough to permit a sealing pressure of 100 lb. per sq. in., but to avoid straining the tube a yielding gasket ring may be placed between the sample and the end plugs. In these experiments thin pads of surgical absorbent cotton were used, and the outlet cotton was frequently replaced. The reason for these cotton plugs is as follows: In the oil field every small volume of oil sand is subject to the capillary attraction of the adjacent sand. If one were to remove

bodily a length of sand and continue to blow gas through it, there would be an accumulation of oil at the outlet face, which is not present when the sand is in place, because this accumulation would have been steadily absorbed by the capillarity of the downstream sand. In short, the presence of a discontinuity in sand structure constitutes a barrier to the transfer of oil that is not directly related to the permeability change. In the experiments, therefore, a pad of cotton, dry enough to absorb the oil as fast as it was produced from the core, was kept at the outlet end in order to simulate conditions in the main body of the field.

It is clear that this shift does not correct for the discontinuity at the inlet end of the core. In order to measure the true transfer coefficient as it is in the field, it may be necessary to arrange some device of porous materials to feed oil into the core as rapidly as it is blown out, thus measuring the quantity of oil moved by the drive at constant saturation, and without a discontinuity in capillary conditions at either end. In these experiments the loss of saturation of a core that has a fractured face on both ends is measured, and an attempt is made to simulate continuity of capillary conditions by keeping absorbent cotton at the end that yields oil.

The same pressure drop was used for every core; namely, from 40 lb. per sq. in. greater than atmospheric to atmospheric pressure.

No elaborate attempt was made to hold down error, since it was observed that the natural variability of the oil distribution in the core, and consequently of the rate of flow of air through the core, made impossible any close reproducibility of the results. The measurements of mass of oil in the core are probably accurate to 0.1 per cent, but the saturations stated are possibly in error as much as 3 per cent because of error in the measurements of pore volume. The oil viscosities were measured at room temperature (generally within a few degrees of 75° F.) and no attempt was made to thermostat the apparatus. The error of the capillary flow meter was as great as 10 per cent for some of the slow rates. The principal error involved in the measurement of rate of flow of the driving air arises from the fact that the conditions within the core vary continually, and sometimes sharply. This variability is a peculiarity of the oil production process, and cannot be avoided. The reading for flow had to be taken more or less on the wing.

After the core was removed for weighing, the rate of flow of gas was generally abnormally low for a short time, while equilibrium was being established. Eventually it may be possible to refine this experiment, but for the present it is intended to draw conclusions that can be based on the consistency of the results of repeated experiments as herein presented rather than on any quantitative guarantee of precision for any given datum.

It should be observed in passing that the pressure gradient used here is far greater than any encountered in practice except in the neighborhood of the well. Probably it is so great as to blot out any possible influence of the Jamin effect. This pressure was chosen because of the great length of time necessary to carry out experiments at lower pressures without automatic apparatus. Perhaps the most serious error in these measurements is the loss of oil by direct solution in the driving air. It is difficult to calculate the loss of kerosene by such evaporation. It should be noted, however, that during the procedure for saturating the test cores, the oil is subjected to vacuum long enough to distill off the lighter and more easily evaporated fractions. Measurements of the rate of evaporation of a core in open air showed a loss of $\frac{1}{1000}$ gram in 25 minutes, or about 0.1 per cent.

Nomenclature

K, permeability in darcies. A material has a permeability of one darcy if through a face of one square centimeter, which is normal to the direction of flow, one milliliter per second of fluid having viscosity one centipoise is caused to flow by a pressure gradient of one atmosphere per centimeter.

o, porosity. The porosity is the ratio of void space in the sandstone to the bulk volume of the sandstone.

s, saturation of oil, expressed as ratio of volume of oil to pore volume.

$F(r)$, number of capillaries per square centimeter that have radii between r and $r + dr$.

$f(s)$, number of capillaries that are cleared of oil when the saturation is changed from s to $s - ds$.

n, total number of capillaries per square centimeter of sandstone.

r_s, radius of curvature of oil-gas interface in a sandstone having saturation s.

t, time.

p, pressure.

v, volume of air forced into or through the core sample.

r, radius of oil-gas interface.

a, radius of a cylindrical capillary tube.

l, length of a cylindrical capillary tube.

γ, surface tension of oil.

η, viscosity, in centipoises.

μ, viscosity in poises (c.g.s. units).

c, d, e, constants.

Discussion of Saturation-time Data

Fig. 2 shows curves of saturation against blowing time plotted on logarithmic coordinates. The more permeable cores give up their oil

more rapidly, as might be expected, since the rate of dissipation of air-drive energy within them is greater. No evidence can be found in these curves to show that there is any minimum saturation below which oil will not be produced. B28 (crossed circle), the core having greatest permeability, shows a repeated tendency to decrease its production rate abnormally after about fifteen minutes.

The law of production against time appears to be a complicated one. The curves as shown on logarithmic coordinates are convex upward, away from the axis of time. When plotted on semilog paper, with saturation on the Cartesian ordinate, the curves are convex downward toward the logarithmic time axis. A number of attempts were made to represent these curves with an empirical equation. A reasonably good approximation for the curves of all the runs with oil A, viscosity 66 centipoises, is given by:

$$S = \frac{S_0}{1 + 0.505K^{0.81}e^{4.57(\log_e t)0.6}} \qquad [1]$$

Here t is in minutes and S_o is the initial saturation. It appears, however, that the exponent of $\log_e t$ is not constant for oils of every viscosity. Since the equation is too unwieldy for purposes of analysis, no attempt was made to patch it so as to include all viscosities. A more fruitful approach is found in the study of the relation between rate of loss of saturation and the flow of energy. This approach is followed in a later section of this paper.

It will be instructive to deduce the form a curve of this type should have in connection with a single circular tube under assumed conditions.

Assume that the tube of radius a has within it a central core of flowing gas and against its walls a cyclindrical shell of oil of internal radius r. If the saturation s is defined as the ratio of the volume of the oil to the volume of the tube,

$$s = \frac{\pi l(a^2 - r^2)}{\pi la^2} \qquad [2]$$

where l is the length of the tube, or

$$r^2 = a^2(1 - s) \qquad [3]$$

Following the usual derivation of Poiseuille's law[3], the relative volume of oil passing any cross section of the tube, if μ is the viscosity of the oil and $\frac{dP}{dl}$ the pressure gradient in c.g.s. units, is:

$$\frac{ds}{dt} = \frac{-1}{8\mu a^2 l}\frac{dP}{dl}(a^2 - r^2)^2 \qquad [4]$$

[3] See, for example, Page: Introduction to Theoretical Physics, 231.

Substituting equation 3 in equation 4,

$$\frac{ds}{dt} = -\frac{a^2}{8\mu l}\frac{dP}{dl}s^2 \qquad [5]$$

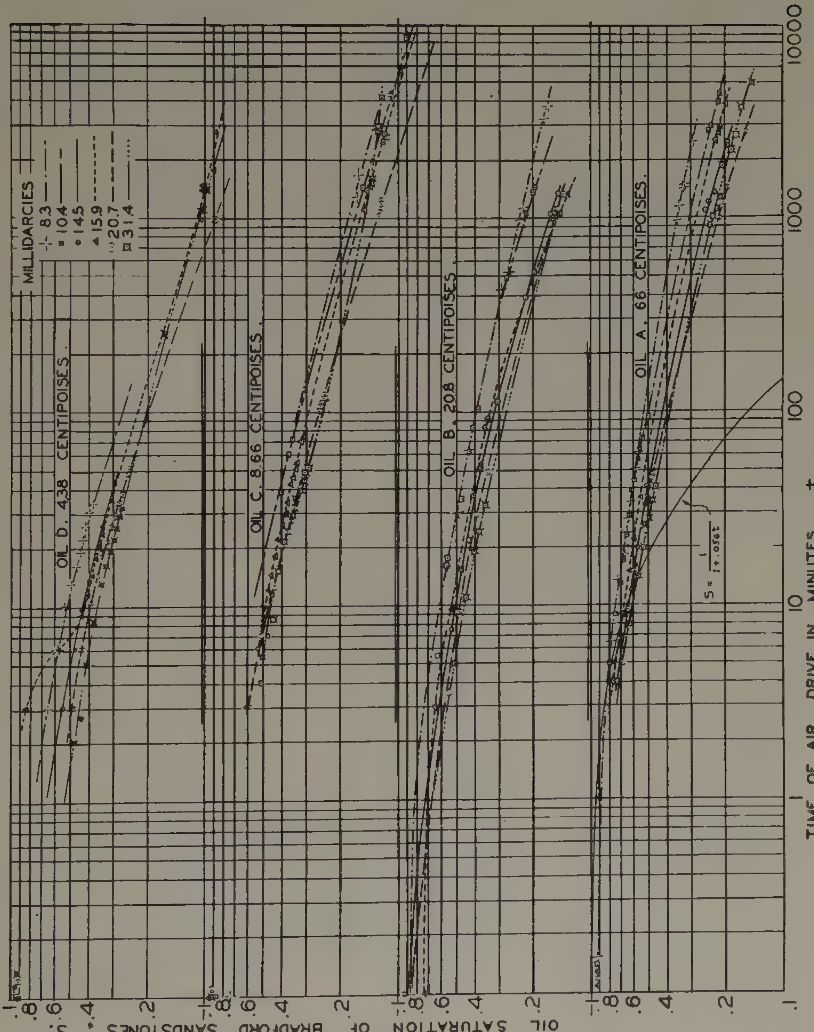

FIG. 2.—CURVES OF SATURATION AGAINST TIME OF BLOWING WITH AIR.

Integrating eq. 4:

$$\frac{1}{s} = \frac{a^2}{8\mu l}\frac{dP}{dl}t + \text{constant} \qquad [6]$$

Assuming that time t is zero when saturation s is one, the constant of integration becomes one.

From eq. 6, we arrive finally at the formula:

$$s = \frac{1}{1 + Ct'} \qquad \text{where } c = \frac{a^2}{8\mu l}\frac{dP}{dl} \tag{7}$$

This, then, is the formula for variation of saturation with respect to time, if the assumption be made that the oil is cleared by a process of

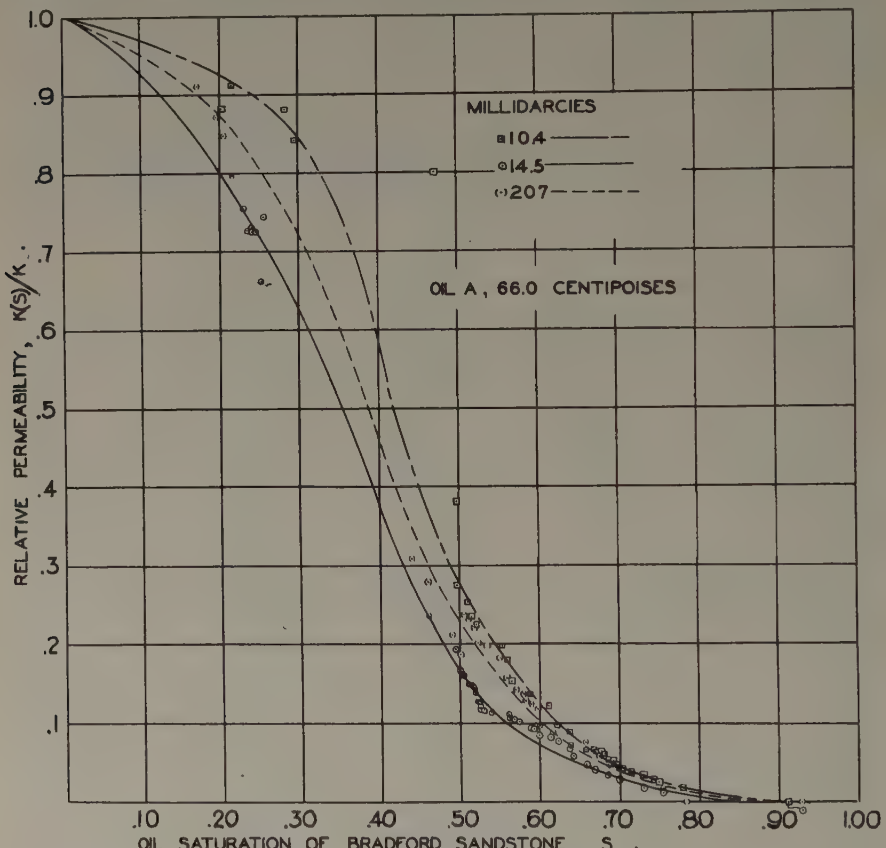

FIG. 3.—CURVES SHOWING PROPORTION OF GAS-CARRYING CAPACITY OR PERMEABILITY AVAILABLE TO DRIVING AIR DURING PROGRESSIVE PRODUCTION OF DEAD OIL FROM INITIALLY SATURATED CORES.

viscous drag rather than by direct displacement of a driving head of gas acting as a piston. The formula is valid for a single cylindrical capillary. The sandstone may be regarded as an assemblage of such capillaries having various radii and lengths. These capillaries will not all begin to be cleared of oil at once; only the larger pores will yield their oil at the first passage of gas, so that the zero of time for the various capillaries treated as in formula 7 will occur at successively later instants for successively smaller capillaries.

Therefore, in order to pass judgment on the applicability of formula 7 to the data, it is necessary to inquire whether it is possible to fit the experimental curves by a sum of terms such as the right-hand side of formula 7, in which the numerator of each term is proportional to the volume of oil in those capillaries that have radii corresponding to the respective value of c,

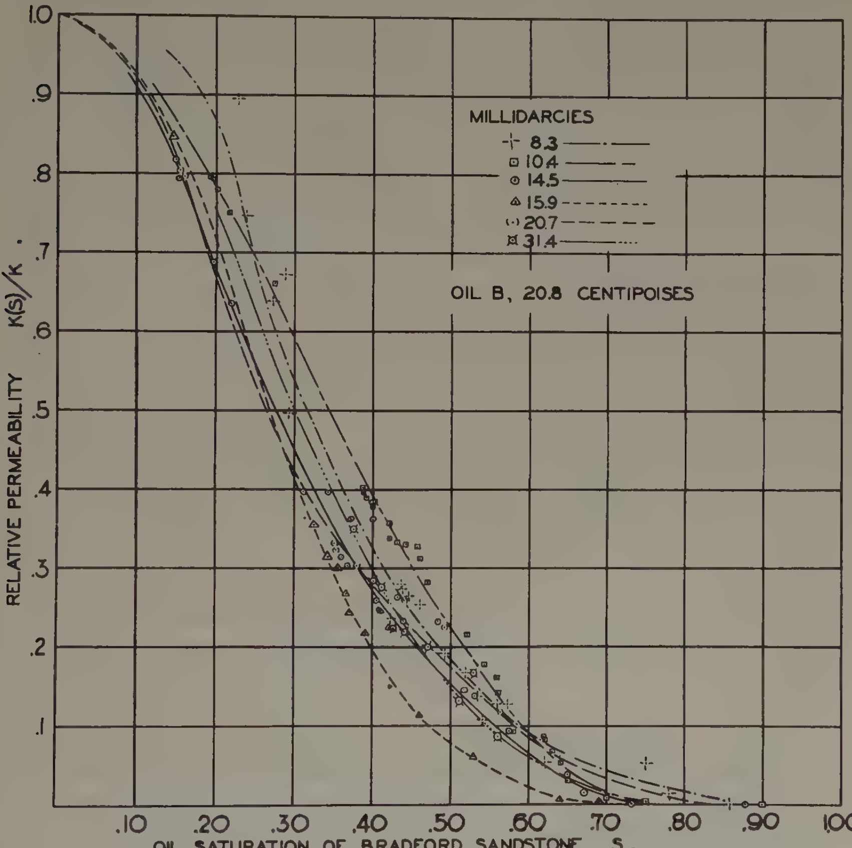

FIG. 4.—CURVES SHOWING PROPORTION OF GAS-CARRYING CAPACITY OR PERMEABILITY AVAILABLE TO DRIVING AIR DURING PROGRESSIVE PRODUCTION OF DEAD OIL FROM INITIALLY SATURATED CORES.

and in which the zero of t in each term is adjusted to correspond to the instant when the respective range of capillary sizes denoted by c begins to flow. It would be difficult to discuss this question rigorously, but it appears to be reasonable to suggest that such a fit can be obtained approximately.

Part of a curve of formula 7 for which a is taken to be one micron is plotted on Fig. 2 among the curves of oil A. It may be seen that the curve of formula 7 is like the experimental curves in that its slope increases with time. Upon substituting the limits of time (0 and ∞) in the formula

we note that the possible range of values is between zero and one, as in the experimental curves. Curves very similar to the experimental curves can be obtained by a sum of terms such as formula 7. It is more difficult

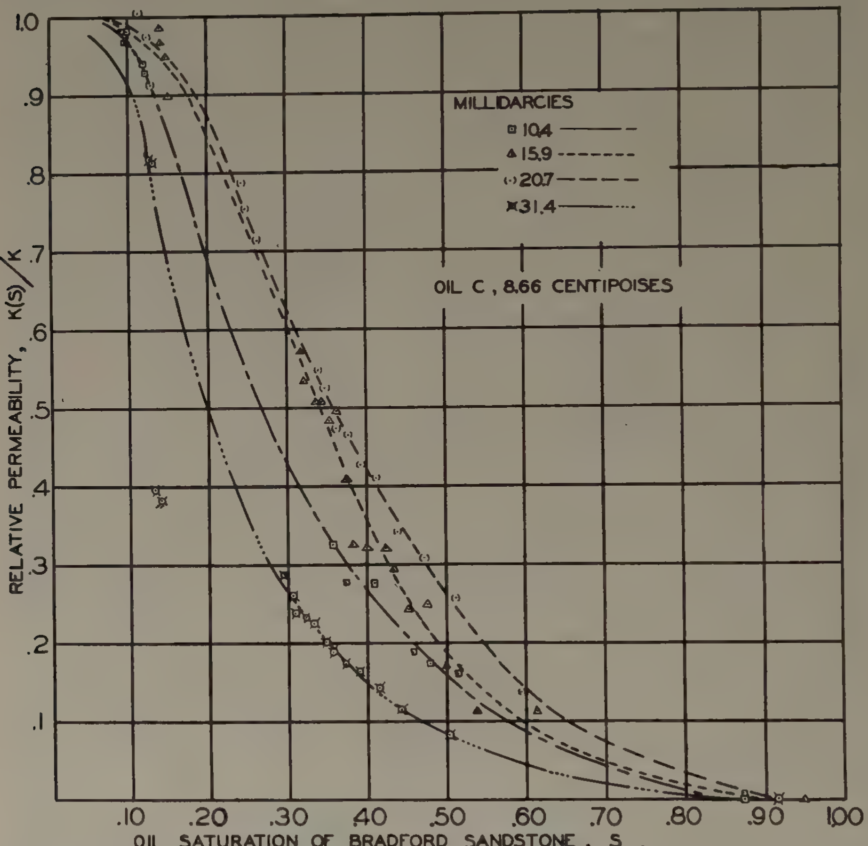

FIG. 5.—CURVES SHOWING PROPORTION OF GAS-CARRYING CAPACITY OR PERMEABILITY AVAILABLE TO DRIVING AIR DURING PROGRESSIVE PRODUCTION OF DEAD OIL FROM INITIALLY SATURATED CORES.

to fit the low-saturation end of the curve in this way than the high-saturation end.

Effect of Removal of Dead Oil by Air Drive on Permeability of Sandstone

At the first instant of our experiment, the sand, being completely blocked with oil, is impermeable to gas. As oil is driven out by the drive the permeability[4] rises with diminishing saturation in a way that is

[4] For a full discussion of permeability and its measurement see Fancher, Lewis and Barnes: Some Physical Characteristics of Oil Sands. Mineral Industries Experiment Station *Bull.* 12 (1933) 135. The Pennsylvania State College, Mineral Industries Experiment Station.

reasonably reproducible for any given sandstone. By taking a continuous record of saturation and rate of flow of gas, it is possible to calculate, for each instant, the permeability the sandstone-oil complex would have if the oil were suddenly frozen into its position.

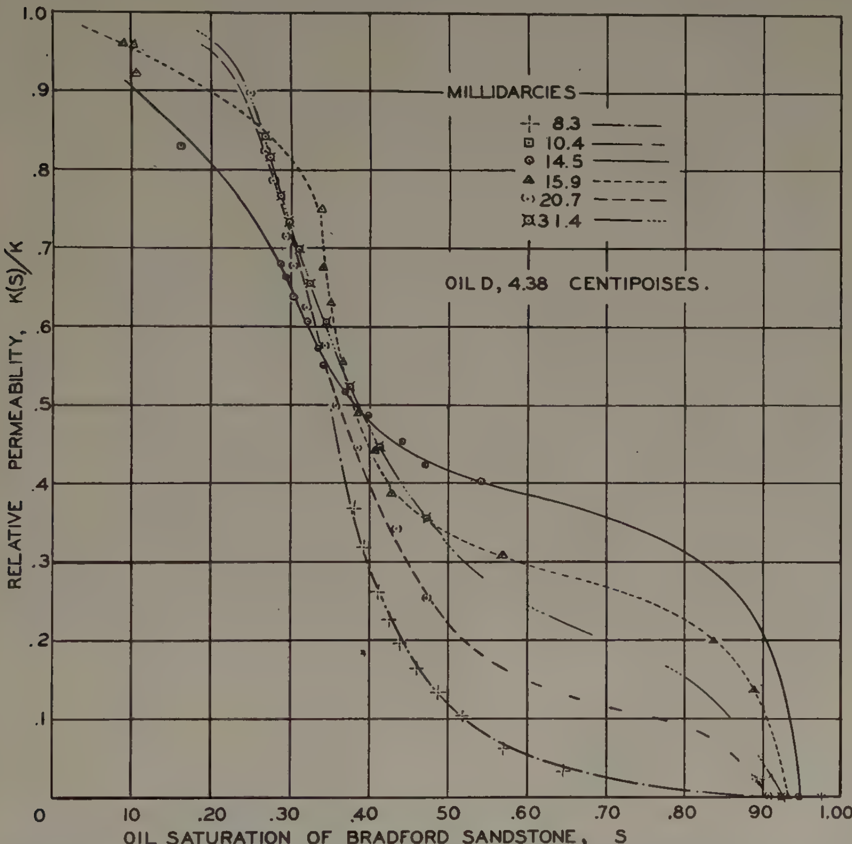

FIG. 6.—CURVES SHOWING PROPORTION OF GAS-CARRYING CAPACITY OR PERMEABILITY AVAILABLE TO DRIVING AIR DURING PROGRESSIVE PRODUCTION OF DEAD OIL FROM INITIALLY SATURATED CORES.

The use of a concept such as $K(s)$, the permeability of a core having saturation s, involves the assumption that whenever a chosen sandstone has a given saturation the oil will distribute itself within the core in only one way. It is obvious that if gas is permitted to come out of solution in the sandstone during the experiment the distribution of oil may be profoundly different from the corresponding case of entirely dead oil, because, although oil cannot be driven out of the smaller pores or out of the cul-de-sacs of sandstone by direct drive this may happen if live oil expands in the core. The results of these experiments are limited in their application, therefore, to an occurrence seldom found in practice.

In the curves of Figs. 3, 4, 5 and 6 are plotted not $K(s)$, but $K(s)$ divided by the "dry" permeability K, in order to reduce all the cores to a common basis of comparison. These curves have the same general shape, with the exception of one or two of the curves of Fig. 6. Since all experiments were performed at the same pressure gradient, it cannot be said that

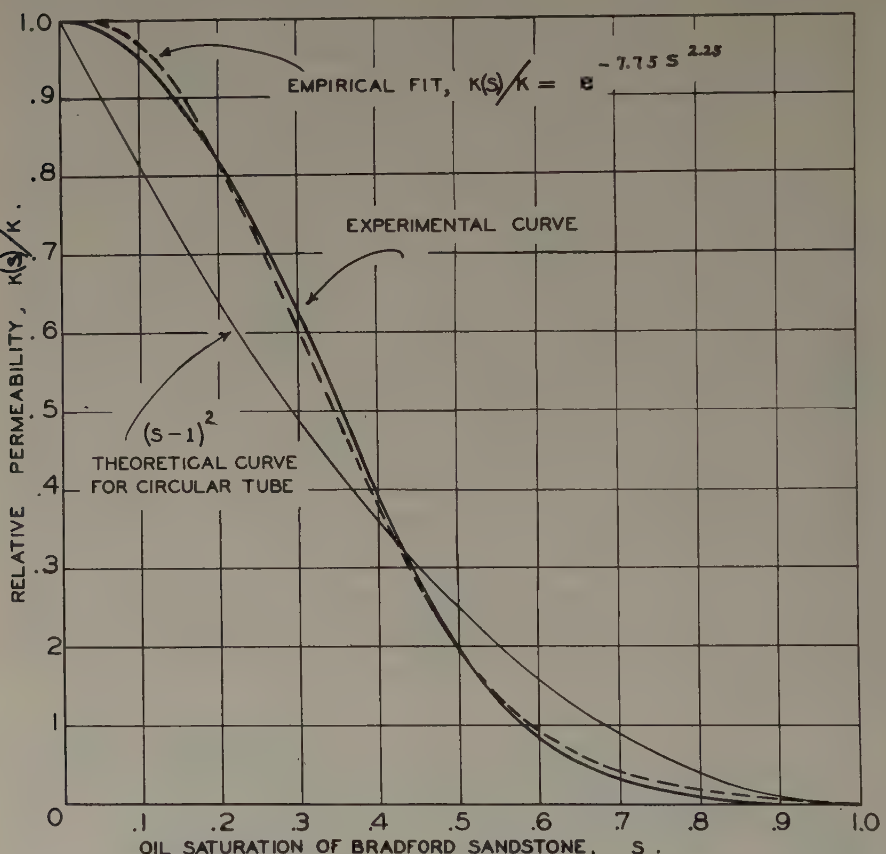

FIG. 7.—AVERAGE EXPERIMENTAL CURVE FOR PROPORTION OF PERMEABILITY AVAILABLE TO FLOWING GAS.

Obtained by averaging curves of Figs. 3 and 4, plotted alongside the empirical fit and the curve that might be expected from a single capillary if it were cleared of oil without the action of a driving meniscus.

this shape of the curve will persist at every pressure gradient. It would be expected that at driving pressures that are so low that the back-pressure ascribable to bubbles formed in the sand is important, the relative permeability $K(s)/K$ would be lower at the higher saturations than shown.

Another possible undetermined factor is the effect of varying pressure gradients on the distribution of oil among the capillaries of the sand. It should be observed, however, that the oil is held tightly by the sandstone.

An oil-gas interface of which the radius of curvature is of the order of one or two thousandths of an inch is relatively rigid, and is not likely to be disturbed by any ordinary pressure gradient unless the pressure is applied directly to the interface, as in the Jamin effect.

The fact that $K(s)/K$ approaches unity at values of the saturation greater than zero would seem to mean that at low saturations oil is held only in the smaller capillaries, which contribute relatively little to the permeability of the core when the core is dry.

An average curve derived from the data of Figs. 3 and 4 will fit the formula:

$$\frac{K(s)}{K} = e^{-7.75s^{2.25}} \qquad [8]$$

with a maximum error of 3 per cent. The similarity to the equation for the probability curve e^{bx^2} is suggestive of a relation between this curve and a probability distribution of capillary sizes. The average experimental curve is shown on Fig. 7 as a full-line curve. The curve of equation 8 is shown beside it as a dotted curve.

It would be expected that in a production process involving only dead oil the oil in the larger holes would be driven out first, and that the smaller capillaries would then be cleared out in order of decreasing size as the saturation decreases. To state this idea in the form of equations, a function of the radius of the capillaries, $F(r)$, is defined, which denotes the number of capillaries to be found per unit increment of capillary radius dr. Thus, if n is the total number of capillaries found in any square-centimeter section of the sandstone,

$$n = F(r)dr_s. \qquad [9]$$

According to this statement, for any saturation s of the sandstone there exists a critical capillary radius r_s; all capillaries of greater size are cleared of oil, and all the smaller ones remain filled with oil. This critical radius r_s will be a function of the saturation. As a result of this assumption it follows that there must exist a frequency function $f(s)$ such that

$$f(s)ds = n \qquad [10]$$

This corresponds to the ordinary frequency distribution function $F(r)$, in this way:

$$f(s)ds = F(r_s)dr_s \qquad [11]$$

The reasons for making the assumption defined above are as follows: The larger capillaries offer less viscous resistance to the removal of oil in accordance with the fourth power law of flow. They should therefore be

cleared out first. As the gas moves against any capillary, a capillary back-pressure will be developed against the entrance of gas, and the meniscus that offers this back-pressure is roughly in the form of a hemispherical cap or driving head at the front of the gas. Since the back-pressure will accordingly be inversely proportional to the radius of the capillary, the surface tension will tend to direct the air into the larger channels first. If the pressure difference applied across this meniscus by the gas is too small to permit entrance of the gas, the clearing out of these smaller capillaries must wait until the dragging effect of flowing gas in the larger channels has reduced the quantity of oil in the larger capillaries to the point where the remaining oil lies only in the bottom of the angles and crevices of these larger capillaries. In this condition the radius of curvature of the oil in the sandstone as a whole may be equal to the effective radius in the smaller capillaries. Further production of oil will then cause the oil in the smaller channels to be sucked out in a manner somewhat analogous to the capillary action of the dry parts of a blotter on a wetted spot.

In a sandstone that is being driven by air, this *equality of the radius of curvature of the oil-gas interface* will be maintained even more rapidly than in an oil-wet blotter, for as tiny slugs of oil are forced along through the sand, the capillaries are subjected to a continual filtering action as to their radius. Any capillary smaller in size than the critical radius r_s must catch and hold such slugs of oil, and they can only be cleared before their time by some random impact.

Lastly, it is known that the rate of evaporation of any liquid is greater for the larger radii of curvature; hence when vapor equilibrium is established every oil-gas interface must have the same curvature.

It was shown above that if the plug action of the meniscus driving head is disregarded, the saturation of a circular capillary will be reduced in accordance with equation 7. It is now assumed that this driving head is all important, and that the various capillaries are cleared instantly as soon as the critical radius r_s is reduced far enough, and on this basis an attempt will be made to account for the shape of the curve of equation 8.

According to Poiseuille's law, the gas-carrying capacity of a circular capillary is proportional to the fourth power of the radius. Hence, if c_1 is a constant of proportionality,

$$\frac{K(S - \Delta s)}{K} - \frac{K(s)}{K} = c_1 f(s) r_s^4 \Delta s$$

or

$$-\Delta \frac{(K(s)/K)}{\Delta s} = c_1 f(s) r_s^4 \qquad [12]$$

Since the mass of oil contained by a capillary is proportional to the square of its radius, it appears, similarly, that the decrease in saturation of

a core is proportional to the number of capillaries freed of oil multiplied into the square of their radii. Thus

$$\Delta s = c_2 f(s) r_s^2 \Delta s$$

or

$$r_s^4 = 1/c_2^2[f(s)]^2 \quad [13]$$

Substituting eq. 13 into eq. 12 gives:

$$\frac{\Delta(K(s)/K)}{\Delta s} = c_3 \frac{f(s)}{[f(s)]^2}$$

or

$$f(s) = c_3 \frac{ds}{d(K(s)/K)} \quad [14]$$

It has been assumed that only capillaries of largest radius are free of oil when the saturation s is near unity. It follows from the definition of $f(s)$ that the value of $f(s)$ must be small when s is near unity, because the volume of each capillary is proportional to the square of its radius. Similarly the value of $f(s)$ should be large at low saturation. Upon comparing the inverse slope $\frac{ds}{d(Ks/K)}$ of the curves of relative permeability with these expectations, it is seen that $\frac{ds}{d(ks/K)}$ is large at saturations less than 5 per cent, but it is not small for saturation values near unity. On the other hand, it was found above that the saturation-time curve might be fitted for saturations near unity by assuming that the oil is removed by a process of viscous drag, in which the initially penetrating gas was in the form of a thin filament with a negligibly small driving meniscus. It will be shown below that for saturations near unity the permeability curves are consistent with the latter assumption also. This situation suggests that in the initial stages of our experiment the radius of the driving meniscus of the gas is much smaller than the radius of the capillary it penetrates, while in the later stages, with a nearly dry sandstone, the capillaries being cleared by gas are so small that they constrict the driving meniscus so that the action is essentially pistonlike.

A thin filament of gas is not stable in a liquid, but will tend to break up into small bubbles. However, viscous forces are relatively strong in channels of microscopic size, so that it is not unreasonable to postulate that the thin filament of gas is an adequate picture of the average flow condition.

Consider again the cylindrical tube described earlier in the paper, having radius a and filled with oil except for a central core of flowing gas of which radius r is small initially but which increases in time as the flowing gas drags out the oil. An expression may be derived for $K(s)/K$, the

ratio of rate of flow of gas when the oil has concentration s to the rate of flow of gas when $s = 0$ and the tube is dry. Again s will be defined as the ratio of the oil volume to the volume of the tube. Then if the velocity of the boundary of oil is neglected, the following equation follows from Poiseuille's law:

$$\frac{K(s)}{K} = \frac{r^4}{a^4} \tag{15}$$

Substituting eq. 3,

$$\frac{K(s)}{K} = \frac{a^4(s-1)^2}{a^4} = (s-1)^2 \tag{16}$$

This curve is plotted alongside the experimental curve and the empirical curve in Fig. 7. There $(s - 1)^2$ gives a reasonable description of the shape of the curve to the right of $s = 0.8$ where the argument above, attempting to interpret the curve in terms of the flow in a distribution of sandstone capillaries that are successively cleaned out completely in order of decreasing size, is not valid.

It may be concluded that if the two conceptions could be combined into one theory the experimental curve could be accounted for with reasonable completeness.

To sum up this interpretation, the following visualization of the flow of gas through sandstones is presented. The gas first enters the larger channels of the sandstone in the form of thin branching tubes, each tube headed by a meniscus of which the radius r is determined more by the value of the driving pressure than by the size of the tube it penetrates, according to the formula $\frac{2\gamma}{r} = p$, where γ is the surface tension, p the pressure supported by the surface. These interlacing fingers of gas produce only a small amount of oil by direct displacement, but the subsequent flow of gas drags the oil along the walls and carries forward not only the oil that was originally within the larger channels but also some of the oil from near-by communicating channels and pores of smaller size. As this process proceeds the oil is removed from successively smaller pores, and these pores are added to the system of oil-carrying channels. The curvature of the oil-gas interface is everywhere about the same. (This curvature of the surface of oil within the larger tubes increases by moving farther down into such sharp angles as may be subtended at the points of contact of the sand grains.) As the curvature increases the smallest capillaries are finally penetrated. The smaller the capillary, the greater is the proportion of oil that is removed at first entrance of the gas, so that in the last stages of oil removal the full gas-conducting capacity of each new channel is effective practically as soon as the gas enters.

Study of Oil-gas Ratio for Sandstones that Bear Only Dead Oil

From the curves of oil saturation against time of air drive described above, and the curves of relative permeability, values of ds/dt and dv/dt

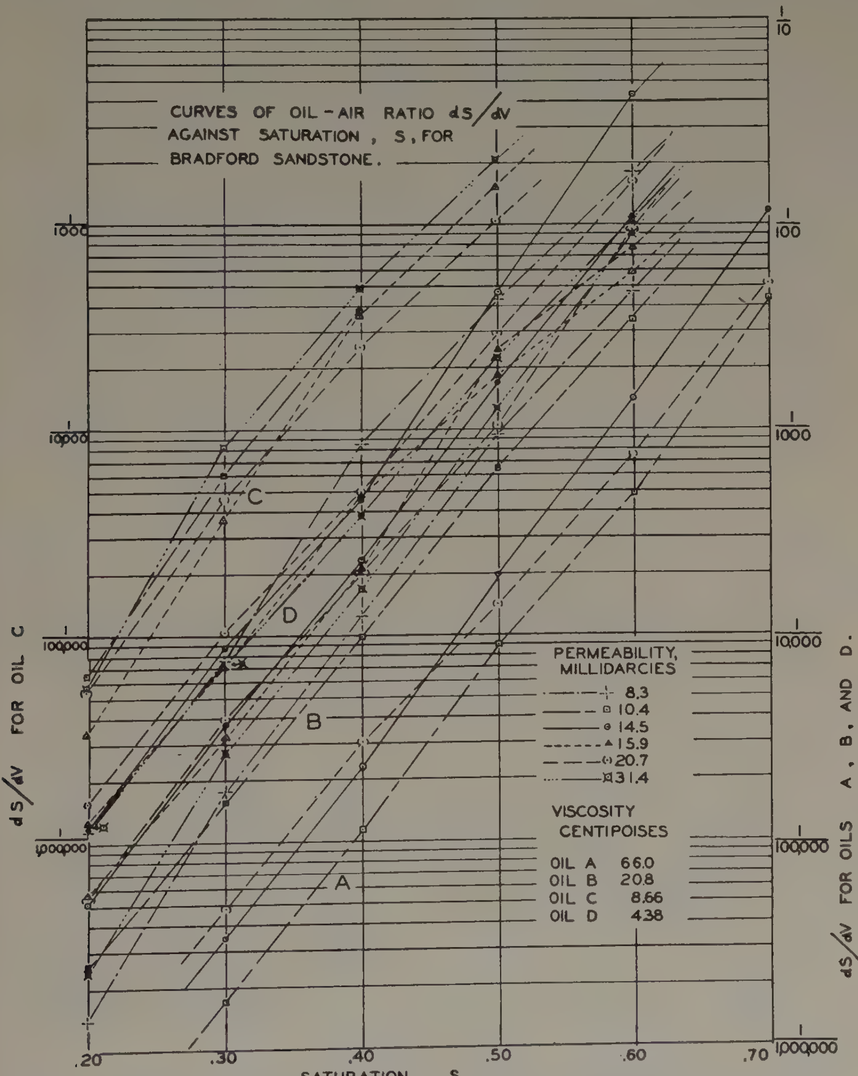

Fig. 8.—Summary of data on oil-air ratio during progressive exhaustion of sandstone.

Note that ordinate ds/dv is not the absolute oil-air ratio. It is the oil-air ratio divided by the porosity. Volume unit is cubic centimeter per square centimeter of sand.

can be obtained. Upon dividing ds/dt by dv/dt values of ds/dv result. This is the rate of production of oil from the core sample with volume of

gas necessary to produce it. The quantities were read from the smoothed curves shown in order to avoid irrelevant irregularities of the data, and were taken at 10 per cent intervals of saturation.

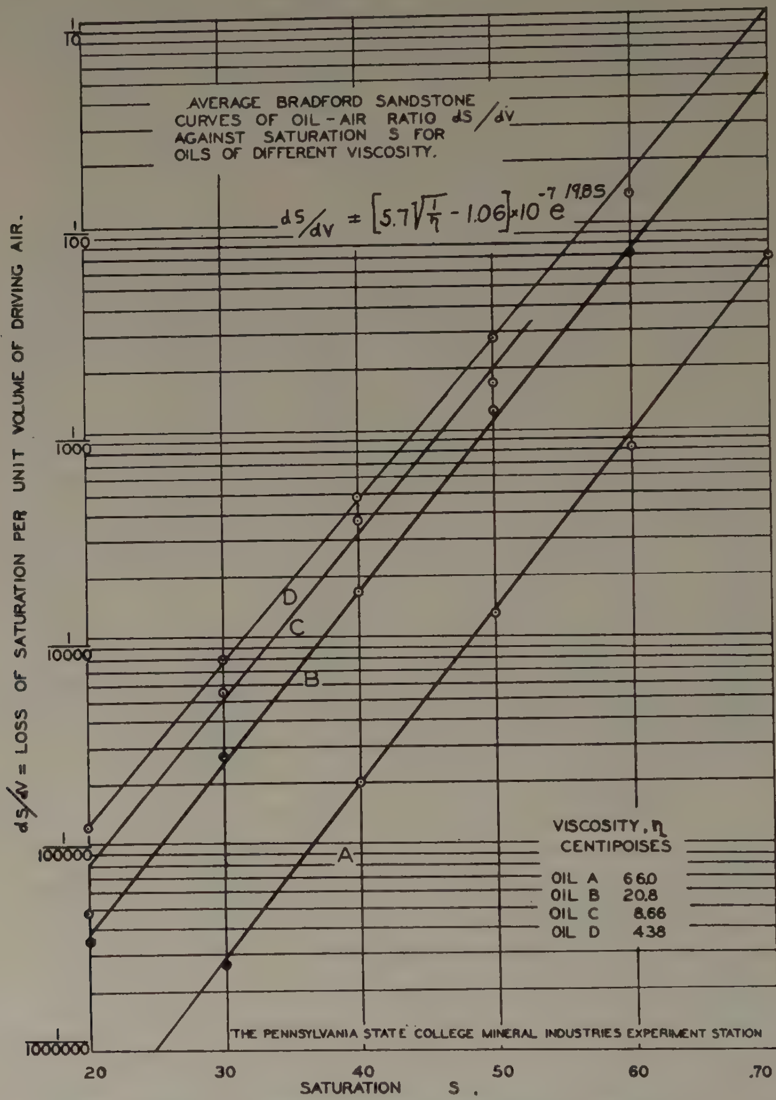

FIG. 9.—POINTS OF FIG. 8 AVERAGED FOR EACH SEPARATE OIL, SHOWING FIT OBTAINED WITH EMPIRICAL EQUATIONS.

The results, obtained separately for each run of data, are plotted in the curves of Fig. 8. The oil-air ratio, expressed as fraction of complete saturation removed per cubic centimeter of air driven through a square centimeter of cross section, is plotted on a logarithmic ordinate, while the saturation is plotted along a Cartesian abscissa.

The curves lie in separate groups according to the viscosity of the oil used in the experiment. Those of A, B and D are best interpreted as straight lines having approximately the same slope; i.e., straight lines would represent *average* performance. There appears to be no regular variation of oil-gas ratio with permeability or porosity; the curves lie in somewhat different relative positions in each group. It is possible that more extensive studies will show such a relation or tendency toward one, but no conclusions can be drawn as yet from these data.

The curves for each viscosity were averaged separately; where curves are missing because of faulty flow data, the average was so weighted as to include them in the relative position they would have had as estimated from their place in adjacent viscosities. The curves obtained in this way are intended to represent the effect of viscosity of the oil on the efficiency of production as revealed by the oil-gas ratio. They are plotted on Fig. 9.

The equations of the straight lines drawn through the points are, for oil A (viscosity 66.0 centipoises),

$$\frac{ds}{dv} = 8.69 \times 10^{-9} e^{19.8s} \qquad [17]$$

For oil B (viscosity 20.8 centipoises),

$$\frac{ds}{dv} = 7.31 \times 10^{-8} e^{19.4s} \qquad [18]$$

For oil C (viscosity 8.7 centipoises),

$$\frac{ds}{dv} = 1.22 \times 10^{-7} e^{20.0s} \qquad [19]$$

For oil D (viscosity 4.8 centipoises),

$$\frac{ds}{dv} = 2.11 \times 10^{-7} e^{20.1s} \qquad [20]$$

A study of the relations of the constants to the viscosity seems to show that the rate of oil production varies with the square root of the fluidity of the oil, so that an approximate law for the average production from the cores used in these experiments can be written:

$$\frac{ds}{dv} = \left[5.7\sqrt{\frac{1}{\eta}} - 1.06\right] \times 10^{-7} e^{19.8s} \qquad [21]$$

These data suggest that where oil is to be driven from the sand in a dead condition, as in some gas-drive properties, the increase in efficiency to be obtained by reducing the viscosity of the oil (by increasing the proportion of gas to air in the driving gas) depends to a considerable extent on the viscosity of the oil before the alteration is attempted.

The average points of oil D and oil C on Fig. 9 suggest that for light oils the curve of log ds/dt would be better represented by curves that are convex upward. Indeed, it is quite clear on theoretical grounds that these graphs must have such curvature at high saturations, because at full saturation the production must be by direct displacement, and ds/dv will not change at all with saturation until the first gas has blown through. In this region the volume of oil displaced, which may be written $o\Delta s$, is equal to the corresponding volume of the gas Δv that has been forced into the sandstone.

$$\frac{\Delta s}{\Delta v} = \frac{1}{o} \qquad [22]$$

Substituting this into eq. 17 (oil A) gives:

$$\frac{1}{o} = 8.69 \times 10^{-9} e^{19.8s}$$

where $o \approx 0.148$, from which it should be possible to calculate the average value of s where direct drive ceases and the law $\frac{ds}{dv} = 8.69 \times 10^{-9} e^{19.8s}$ begins. Our solution for s is 1.06 if the average porosity (0.148) for the cores used is substituted. This implies that for oil A the region of direct drive is extremely small, or, in other words, the gas penetrated through the short core and began producing by viscous drag before any significant amount of oil was driven from the core.

A similar calculation of the lower limit of saturation for direct drive for oil B yields $s = 0.94$. Thus 6 per cent of the oil may have been driven out by direct displacement. For oil D we obtain $s = 0.86$.

It cannot be expected that the transition from the equation $ds/dv = 1/o$ to the equation $ds/dv = ae^{bs}$ will take place sharply at the critical saturations calculated above; one would predict rather that as the saturation decreases toward the critical saturation the horizontal line $ds/dv = 1/o$ will bend down slowly into the curve $ds/dv = ae^{bs}$. Possibly the low point on the curve of average performance of oil D (Fig. 9) and the definite curvature of oil C are expressions of this tendency to bend over toward the horizontal line, which is believed to be the true law near complete saturation. It is probable that further measurements at lower driving pressure now under way in this laboratory will do much to clear up this question, but for the present the exponential equation for ds/dv in the region between 20 and 70 per cent saturation is presented as a good formula to represent average conditions, with the remark that the law must fail at higher saturations for the reasons described.

Summary and Conclusions

In these experiments the purpose was to determine the effect of the sandstone and the viscosity of the oil on the production of oil in the

simple case where no expansible gas is dissolved in the oil, and it was intended if possible to obtain laws that involve elementary quantities usable in differential form, so that the processes of mathematical analysis can be used to solve the problem of well performance.

Short, homogeneous cores of known permeability and porosity were saturated with "dead" oils of known viscosity and surface tension. These were cleared of oil by blowing with air at a constant pressure gradient of 42 lb. per sq. in. per inch, under such conditions that the saturation and rate of flow of gas could be followed with time.

A reasonably accurate but cumbersome empirical expression for the loss of saturation with time was obtained for an oil of 66 centipoises in the form:

$$s = \frac{s_o}{1 + 0.505K^{0.81}e^{4.57(\log_e t)0.6}}$$

which indicates the nature of the variation of production with permeability of the sand.

A formula for the variation of saturation with volume of gas driven through the sand was found:

$$\frac{ds}{dv} = \left[5.7\sqrt{\frac{1}{\eta}} - 1.06\right] \times 10^{-7}e^{19.5s}$$

An average equation for the variation of permeability with saturation was obtained:

$$K(s) = Ke^{-7.75s^{2.25}}$$

An attempt was made to provide a simple theoretical background for these formulas.

Acknowledgments

The authors wish to express their gratitude to Dr. A. W. Gauger, Research Director at the Mineral Industries Experiment Station, The Pennsylvania State College, for his continued support and encouragement.

Water-flooding in the Mid-Continent

By George H. Fancher* and Kenneth B. Barnes†

(Houston Meeting, October, 1935)

With the advent of water-flooding into active commercial usage in half a dozen areas in the Mid-Continent, the process passes the experimental stage and joins other methods and processes now in use which have been found suitable in one oil field or another in securing a more profitable production than has existed heretofore. The use of the air-gas lift, acidization, pressure maintenance and repressuring have presented their problems in economics and engineering during their introduction and extended application. When a new field is discovered or attention is turned to an old producing area in which these methods have not been considered, it is to be expected that these problems again arise. While some information is available as to the results obtained by water-flooding in a few localities in the Mid-Continent, the extrapolation of the sand data on which the results are based, for even generalized use in other areas and fields in the region, is hazardous. It is precarious to assume that the same physical condition will obtain in a sand over more than small, special areas.

This paper is concerned with a brief presentation of such data as are available to the authors on existing operations, a survey of the region and extent to which application of the method seems most likely to be made, an estimation of the crude reserve existing for such operations, suggestions as to the importance of core analysis in guarding against uncontrolled floods and its usefulness in predicting ultimate recoveries, and comment on some of the economic phases involved. These subjects, as concerned with water-flooding in the East (notably Bradford, Pennsylvania), have been discussed in detail in the literature and are generally well known. Especially is this true of discussions of the mechanical equipment and various lease layouts and development patterns for water-flooding.

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History

Contrary to general opinion, water-flooding is not new to the Mid-Continent. Advantage has been taken of so-called natural floods caused by leaking casing for over 20 years in Chautauqua County, Kansas, and probably in a good many other areas if the truth were known. Evolution naturally led to a technique involving the slitting of casing opposite water sands in edge wells, estimating the direction and progress of the water so admitted, drilling of new oil wells to keep abreast of the flood and the eventual conversion of these wells to water wells after the flood had passed them. It should be noted that in most cases this practice utilized salt-water brines in contradistinction to similar methods employed in the East. Results by such methods have been highly satisfactory in some cases, despite the crude methods used. Since the intentional admittance of water of any kind to an oil sand has until recently not only been viewed askance by the industry at large but also has been illegal, neither results nor methods have been discussed openly.

Fortunately the need for secrecy in this respect has passed. Water-flooding is approved by the industry. The Legislature of the State of Kansas, in the spring of 1935, with the approval of the Governor, legalized the use of water in repressuring and the disposal of waste waters in suitable substrata. Likewise the Corporation Commission of the State of Oklahoma has issued permits for water-flooding in suitable circumstances. It seems probable to expect that other states will follow suit in enacting this advanced legislation.*

The first systematic flood in the Mid-Continent was started in 1931 in Rogers County, Oklahoma, in the south end of the Alluwe field, in the Bartlesville sand. Development is being continued in this and other parts of the Nowata field. Other floods in the Mid-Continent are in Creek County, Oklahoma, in the Red Fork sand, Osage County, Oklahoma, in the Bartlesville sand, Chautauqua County, Kansas, in the Peru sand, and Greenwood County, Kansas, in Bartlesville sand.

Characteristics of the Process

Before considering the subject of what may and may not be suitable sands, fields and areas in the Mid-Continent for water-flooding, a survey of some of the characteristics of the process should be made. The process is used for the reasons:

1. It may produce oil that could not be recovered by natural methods of production. Usually this is the case with oil sands that lack a natural water drive. Leases are known that would not have recovered 1000 bbl.

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* Since this paper was written two permits allowing controlled water-flooding have been granted by the Railroad Commission of Texas, one for the Fry pool of Brown County, the other for Wichita County, Texas.

per acre over a very long period of time, as indicated by production-decline curves, but that have obtained 4000 bbl. or more per acre under intensive, properly planned water-floods. One cause for this result is that energy, through the water drive, can be applied in sufficient amount and at selected points and to areas to move some of the oil, contained in the sands that lack energy, to the wells. This energy greatly supplements the only important driving force, the gas pressure, heretofore existent for producing the crude oil. The gas pressure in sands of this type, especially if they have produced for some time, is usually so small as to be almost negligible, and wells produce slowly, as Table 1 indicates.

Table 1.—*Production of Some Stripper Wells in Oklahoma*

County	Number of Wells	Average Production, Bbl. per Well per Day
Nowata	6180	0.89
Rogers	1712	0.50
Washington	3526	0.67

It is also well known, and has frequently been mentioned in the literature, that the gas bubbles occurring in the capillary networks of oil sands are actually a deterrent or obstruction to the movement of the oil to the well. Gas bubbles must be distorted to pass through the reoccurring smaller openings, and energy must be supplied to perform the distortion. In natural production, gas bubbles further back in the sand, and under higher pressure, by their expansion supply the needed energy. As reservoir pressure decreases, a stagnant, greatly enlarged system of bubbles develops, which resists flow. The supplial of energy through the medium of water affords convenient and economical means for overcoming the stagnation of the system and for pushing the gas bubbles through the capillary network. If enough pressure is used some of the gas will return to solution, with attendant beneficial changes in the physical properties of the crude. In repressuring, the energy for distorting and moving the bubbles is supplied by furnishing more bubbles under a higher pressure, with the energy coming from the expansion involved. The bubble system probably is not diminished in size.

2. Successful water-flooding will recover in a short time the dead or unsaturated crude commonly present in stripper fields. For example, a lease may be considered that is at or approaching its economic limit under present conditions. The lease might be made to produce further by one of three methods, with the following results:

a. Pumping, 25 years; yield, 1500 bbl. per acre.
b. Repressuring, 10 years; yield, 2000 bbl. per acre.
c. Water-flooding, 2 years; yield, 3000 bbl. per acre.

Method *a* is obviously impractical, *b* and *c* can be made profitable. The saving in interest, depreciation, maintenance and operating charges, and ad valorem taxes made possible by use of method *c* is evident.

3. The oil saturation of the sand, if sufficiently high, is reduced to a fairly low figure. This, of course, is only another way of stating that the recovery is efficient. The process is generally thought to remove from 35 to 45 per cent of the oil contained in sand of suitable physical properties at the start of flooding. In tight sands it is known that water will remove more oil than will a gas drive, although in loose sands with large capillaries the gas drive may be considerably better if the original oil saturation is low.

4. Water-flooding offers a positive control of oil production. While it is not desirable to simply shut down the water to input wells to decrease production, flood projects are developed in blocks, the total life of which is comparatively short. By planning to develop new blocks in accordance with prevailing economic circumstances, and in necessity restricting the input of water, a control is possible that is not much more difficult than that for ordinary pumping. In fact, one operator has compared it to turning on and off a spigot.

5. The maintenance and operation of water-flood leases, after sand studies and development plans are made, is easy and simple. Labor charges to the operation are low. High pressures are obtained more easily and cheaply in water-flooding than by gas repressuring.

6. Water-flooding based upon competent ore analyses and economic studies becomes simply a mining operation capable of yielding a desired return upon any given investment.

Regional Extent

Consideration of the areas in the Mid-Continent that might be water-flooded clearly demands the imposition of physical and economic limitations. The first restriction, obviously, is that only those oil fields lacking or possessing an inadequate water drive are involved. If only physical limitations are considered, possibly a large number of the oil fields in the Mid-Continent could be flooded with some degree of success. The chief requirements would be that the permeability profile of the sand body be uniform and average not more than 200 millidarcies in permeability, and that the oil content be great enough and in sufficient percentage saturation to assure sufficient recovery. Both laboratory research and field operation have demonstrated that not only is it impossible to strip sand of all the oil held by it by water-flooding but also that the recovery depends upon the percentage saturation and the permeability. It is believed by the authors that it is impossible to reduce the final saturation of a sand of low permeability (5 md.) below 18 per cent; of higher permeability (200 md.) below 15 per cent by methods now practicable.

TABLE 2.—*Oil Fields of Northeastern Oklahoma*

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Ada	Pontotoc	2300 2950	Hunton Simpson	95 5	Small dome	20 Show	
Adair	Nowata	1025	Bartlesville	30–50	Normal monocline	5–150	
Alabama	Hughes	2910	Deaner	400	Terrace	20–200	
Allen	Pontotoc	720 825	Boggy	45 50	Anticlinal folding	10–100 45–200	 1
Alluwe	Nowata	400–450 465–800	Bartlesville Burgess		Anticline	25–500 Oil-gas	
Almede	Osage	1320 1665	Bartlesville Burgess	10 5	Folding	10–50 10–20	1–2
Atlantic	Osage	1125 2500 2690 2750	Layton Burgess Wilcox Siliceous	10 25 20 30 10–20	Anticlinal folding	Show 125–300 Show 3000	
Avant	Osage	1400 1450 1465– 1600	Bartlesville Burgess		Anticlinal folds	75 25–50	1–12
Baird	Cotton-Stephens	2100 2200	Smith Blaydes	65 42	Buried	25–200 5–150	 1–5
Bald Hill	Okmulgee	750 1200 1300 1575 1700 1850 1950 2250	Salt sand Booch Red Fork Morris Glenn of Morris Fields Lyons-Quinn Wilcox	150 40 25 25 40 60 20 50	Terrace	25–50 10–1500 10–200 20–300 10–150 20–50 Oil 100–500	
Barnes	Garfield	2000	Barnes	50	Anticlinal nose	100	
Barnsdall	Osage	1100 1550– 1725	Pery Bartlesville	 75	Domes	8–50 100–300	 1–3
Barlett	Okmulgee and McIntosh	1550 1750 1950 2898	Booch 1st Dutcher 2d Dutcher Wilcox	60 25 60 15	Anticlinal folds	Oil 10–200 20–100 15–100	12 and 15 1–4
Beebe	Pontotoc	1600 2300	Boggy Hunton	150 107	Beebe anticline	10–25 100–125	

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Beggs	Okmulgee	1700 2090	Taneha Dutcher	50 90	Terraces	150–2000 100–300	10–30 1–3
Beland	Muskogee	1270 1650 1700	Muskogee 1st Dutcher 2d Dutcher	25 50 75	Folds and terraces	8–10 25 25–50	
Bilbo	Marshall	420–650	Trinity sand	10–100	Madill anticline	30–200	
Billings	Noble	2000–2225 2620–2800	Hoover Tonkawa		Billings anticline	500 50–100	21
Billingslea	Creek	2390	Prue	50	Terrace	250	
Bird Creek Flat Rock	Tulsa Osage	790 1110 1345	Oswego Bartlesville Burgess	55 95 20	Anticlinal noses	Oil 20–400 10–100	 Gas 5 1–3
Bixby	Tulsa	995 1192 1700 2100	Glenn Taneha Dutcher Wilcox	50 25 70 40	Folding	Oil 200–400 100–150 50–150	
Blackwell	Kay	1600 1750 1900	Ponca Lower Hoover Endicott (?)	10 15 20	Blackwell anticline	100–400 100–135 20–1200	
Boston	Osage	1790 2325 2620	Cleveland Bartlesville Siliceous	 30 60	Surface anticline	50–250 20–3000 100–6000	1
Boynton	Muskogee	1000 1400 1500 1800	Booch Leidecker Boynton Mississippi		Boynton dome	10–150 1–10 50–200 10	 1–7 1–10
Braman	Kay	1900 2100 2387 2800	Hoover Endicott (?) Tonkawa Layton	95 15 45	Anticlines	100–1800 175–500 Oil 100–5000	
Brinton	Okmulgee	1700 2025 2100 2150 2700	Booch Lower Dutcher Glenn Lyons-Quinn Wilcox	20 65 20	Folds	 50 35–60 20–300 20–100 25–300	 1–18

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Bristow	Creek	2700 2800	Dutcher Mississippi	55 20	Surface faults	50–200 20–150	6 1–10
Brock	Carter	1100–2200	Ordovician		Three terraces on a monocline	30–600	3–30
Broken Arrow	Tulsa	1350 1500	Bartlesville Dutcher	20 15	Local anticlinal folding	50–200 10–60	2–4 1
Bruner-Vern	Tulsa	1920 2020	Tyner Turkey Mt.	22	Anticlinal folding	200–500 100–400	
Burbank	Osage-Kay	2700–2790	Burbank	40–80	Monocline	50–5000	
Butler	Muskogee	1213–1268	Sand	47	Subsurface folding	20–100	
Bu-Vi-Bar	Noble	1894–1900	Uncorrelated	6–10	Monocline	10–100	
Canary	Washington	1190 1480	Bartlesville Tucker	55 30	Local folding	5–150 10–25	 1–3
Caney	Washington	615 815 1185 1140	Big Lime Oswego Bartlesville Tucker	20 50 50 30	Local folding	Oil Oil 10–100 10–20	 1–2
Cement	Caddo	1850 1900 2400 2800	Permian	14 15 15	Cement anticline	250 25 50–100 20–50	 1–5
Chelsea	Rogers	400 463 600	Stray Bartlesville Burgess	20 80 40	Anticlinal folding	15–30 20–100 40–60	
Chickasha	Graddy	2450–2475	(?)	10–20	Chickasha anticline	Oil	
Chicken Farm	Muskogee	400 700 1200 1350	Oswego Tucker Boynton Taneha	10 30 10 20	Lenticular sands	10–25 20 20–60 15–150	
Claremore	Rogers	550 810–825	Bartlesville Burgess		Local structure	20–60 10–50	

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Cleveland	Pawnee	500 1300 1700 2090 2180 2400	Kelsa Layton Cleveland Oswego Skinner Bartlesville	30 50 20 20 110	Local structure	Oil 20–125 20–300 75 60 31–1000	 1–5
Coalton	Okmulgee	1300 1930 2835	Booch sand 2d Dutcher Wilcox	100–300	Terraces anticlinal	15–600 Black Green 100	
Cole	Muskogee	1610	Sand	20	Subsurface folding	300–700	
Collinsville	Tulsa	700 1390 1600	Oswego Bartlesville Burgess	30 175 30	Terraces	10–25 20–60 20–30	 1–18
Comanche	Stephens	1400 1800	Wilson 1800-ft. sand		Dome	10–15 100–400	
Continental	Creek	2475 2900	Glenn Dutcher	175 90	Terraces	50–100 50–100	1–3 10–30
Coody's Bluff	Nowata	850	Bartlesville	40	Anticline	25–125	
Copan	Washington	800 1000 1800	Big Lime Oswego Siliceous	50 20 30	Slight folds	Show 20–100 70–150	
Council Hill	Muskogee	600 1000 1650–2100 2400	Salt Booch Dutcher Lyons Quinn		Terraces	Oil Oil Oil Oil	
Country Club	Tulsa	1495 2050 2230	Tucker Wilcox Turkey Mt.	10 120 30	Local folds	Oil 200–2400 50–200	2–4
Coweta	Wagoner	700 1280	Dutcher Burgen	300 400	Seneca fault	5–500 5–30	1–6
Cox	Carter	1250 1300 1415 1550 1623 2910	Pennsylvanian Glenn	10–50	Monocline	5–100	

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Cruce	Stephens	800 1720 1900	Stray Sand Sand	10–20 10	Cruce anticline	5–60 5–40 10–25	
Davenport	Lincoln	2600	Cleveland	50	Anticline	60–100	
Dawson	Tulsa	850	Bartlesville	20	Local folds	25–50	
Deaner-Clearview	Okfuskee	2800	Deaner	40	Dome	50–250	
Deer Creek	Grant	2900	Swaggart	25	Deer Creek anticline	10–300	
Deep Rock	Payne	2072 2500 2900	Cleveland Oswego Skinner	40 30 50	Local folds dome	Oil Oil Oil	
Delaware-Childers	Nowata	190 370 700–850	Big Lime Oswego Bartlesville	20 30 40	Local folds	10–50 Oil 15–150	 1–10
Depew	Creek	2700	Glenn	110	Fault zone	100–200	
Devonian	Okmulgee	1540 2675 2675	Glenn Wilcox Wilcox	60 25 25	Local folds	20 20–200	 1–5
Dewey-Bartlesville	Washington	650 700 900 1265	Big Lime Peru Oswego Bartlesville	70 30 80 35	Anticlinal folds	10–30 30–60 50–60 100–500	
Domes	Osage	1057 1680 1880	Stray Bartlesville Mississippi	67 100 45	Anticlines and domes	10–25 10–110 25–75	 1–3
Donnelly	Creek	2800	Dutcher	20	Folds	15–100	5–15
Doyle	Stephens	1110 1250	Uncorrelated	 5	Dome	10–20 10–50	
Drumright	Creek	2175 2675 2800	Wheeler Bartlesville Wilcox	5–20 50 20	Drumright dome	50–300 250–2000 100–1000	
Duncan	Stephens	1700 2100 2200 2300	Surber Brown Blaydes Kagay		Domes and anticlines	10–1000 50–1000 15–1000 40	 10–70 10–25

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production: Oil, Bbl.	Initial Production: Gas, M. Cu. Ft.
Duquesne	Pawnee	2060 2100 2680	Layton Cleveland Prue	20 60 50	Terraces, local folds	Oil Oil 10–50	
Dustin	Hughes	2900	Lyons-Quinn	70	Local folds	10–50	
Elliott	Nowata	1040	Bartlesville	25	Anticlinal folds	10–250	
Empire	Stephens	1600 1700 1800 1900 2000 2100 2200 2300	Nigh Surber Cantrell Shelton Smith Brown Blaydes Kagay		Dome	10–25 50–100 Oil Oil Oil Oil 15–1000 Oil	 Gas
Enos	Marshall	450	Lower Trinity	25	Preston anticline	1–4	
Eram	Okmulgee	1900 2700	Dutcher Wilcox	15 10	Dome	50–175 100–2000	
Fairfax	Osage	2684 2700	Oswego Burbank	10 42	Local folds	5–45 15–500	1–5 1–6
Fisher	Tulsa	2265 2400	Tyner Turkey Mt.	10 100	Anticline	10–40 250–500	
Foraker	Osage	2750	Mississippi	50	Dome	10–100	
Fox	Carter	1900 2100	Glenn	80 120 60 130	Anticlinal folds	50–600 250–550	
Frankfort	Osage	2040 2905	Peru Mississippi	50 40	Dome	10 Oil	 1–3
French	Okmulgee	1100 1500	Salt Booch	75	Minor folds	50–75 50–250	2–3
Garber	Garfield	1100 1430 1500 2000 2400	Hoy Hotson Walker Garber Hoover	20 20 20 40	Garber anticline	20–150 20–150 10–100 15–100 25–200	
Gilliland	Osage	2400 2500 2775	Bartlesville Mississippi Siliceous	15 100	Anticlinal folds and domes	50 20–50 300–3500	1–3

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Gillette...........	Wagoner	1320	Tyner	200	Small domes	25–75	
Glenn Pool........	Creek	815	Oswego	30	Anticlinal folding	10–20	
		1003	Perryman	35		Oil	
		1225	Red Fork	15		Oil	
		1350	Glenn	20		40–600	2–10
		1550	Taneha	100		10–100	1–4
		1710	Burgess	25		Oil	
			Wilcox	10		70–300	
		2160	Hominy	30		25–100	
		2250	Turkey Mt.	20		30–2000	
Glenoak...........	Nowata	680	Peru		Local folds	2–10	
		1080	Bartlesville			10–50	
		1160	Burgess			5–30	
Gotebo...........	Kiowa	1460	Uncorrtelaed	12	Slight folds	20	
		2825		15		10-25	
Graham...........	Carter	1750–2900	Glenn	5–100	Anticlinal fold	10–950	3–43
		2100–3350		10–125		15–1200	
		2700–3700		5–40		15–100	
Granite...........	Greer	196	Uncorrelated	2	Steep dips	Show	
		330		1		2–3	
		875		5			
		970		3		3–5	
Hallett............	Pawnee	2565	Skinner	35	Local folds	40–100	
Hamilton Switch...	Okmulgee	1385	Glenn	150	Domes	10–100	
		1743	Booch	10		Show	
		2020	Dutcher	20		10–200	
Hanbury..........	Comanche	1530–1640	Uncorrelated		Flat dome	Show	
						10–100	
		1860–2000	Pontotoc	10		20–400	
Harness...........	Grady	1975	Pontotoc ?	25	Anticline	30	
Haskell...........	Muskogee	1360	Tucker (?)	20	Local folds	10–100	
		1900		15		100–350	
Healdton..........	Carter	920–1025	Upper Penn.	30	Anticlinal folds	5–20	
						20–100	
		1130–1320	Glenn			10–3000	
						20–250	
		1730–2000	Healdton zone			10–560	
						10–250	
		2220–2375	Ordovician	175		Show	
				10		Oil	

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production: Oil, Bbl.	Initial Production: Gas, M. Cu. Ft.
Hector............	Okmulgee	800	Salt	100	Local folds	8	
		1200	Glenn	60		Oil	Gas
		1650	Booch	50		Oil	
		1717	Dutcher	3		10–150	
		1862	Mississippi	70		10–75	
		2240	Wilcox	30		50–250	
Henryetta.........	Okmulgee	2630	Lyons-Quinn	20	Local folds	10–700	1–5
Hewitt............	Carter	920–1130	2 Strays	20–60	Two anticlinal domes connected	25–200	
		1200–2000	1st Hewitt			10–150	
		2090	2d Hewitt	15		20–50	
		2170	3d Hewitt	20		30–200	
		2200	4th Hewitt	15		10–50	
		2250	5th Hewitt	30		200	
		2300	6th Hewitt	50		90–400	
		2700	7th Hewitt	40		100–400	
Hickory Creek.....	Osage	750	Peru		Anticlinal folds	Show	
		900	Oswego	30			1
		1000	Bartlesville	45		75–125	
		1300	Mississippi			8–200	1–3
Hoffman...........	Okmulgee	1780	Dutcher	10	Dome	20–60	1–18
		2900	Wilcox	50		200	
Hogshooter........	Washington	1080	Bartlesville		Anticlinal folds	10–500	
Holdenville........	Huges	2660	Glenn (?)		Monocline	10	
Homer............	Carter	480	Pontotoc	20	Plunging anticline	1–5	
Hominy...........	Osage	1720	Peru	25	Anticlinal folds	10–40	
		2040	Bartlesville	10		1–25	
		2265	Mississippi	300		10–2500	
		2540	Hominy	60		20–300	
		2609	Siliceous	70		50	
Hominy Falls......	Osage	1174	Cleveland	20	Anticlinal folds	Show	
		1390	Bartlesville	20		10–125	
		1590	Taneha	55		10–125	1–8
		1750	Burgess	10		10–50	
		2045	Mississippi	20		Oil	
Hubbard or Retta..	Kay	2640	Tomkawa	60	Anticline and fault	100–800	
		2990	Layton	90		100–200	
Humble or Seay....	Jefferson	1100	Uncorrelated	5	Antclinal axis and folding	10	10–70
		1850	Uncorrelated			Show	

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Independent.......	Okmulgee	2100 2550	Dutcher Wilcox	55	Dome	50–100 40–70	1–5
Inola..............	Rogers	540 670	Bartlesville Burgess	60 20	Local variations in normal dip	2–20 1–30	1–2
Iron Post.........	Creek	2320 2420 2475	Cleveland Wheeler Prue	100 25 50	Subsurface folds	Oil 40–100 5–25	
Jenks..............	Tulsa	1400 1600 1750 1800	Red Fork Bartlesville Dutcher Mississippi	20 40 60 40	Local folds	20–40 40–100 10–200 5–40	 1–6 1–2
Jennings..........	Pawnee Creek	2500 2685 2800	Skinner Bartlesville Taneha	55 15 50	Local folds	20–200 100–400 Oil	 1–3
Jolly-Patton.......	Muskogee	512 675 107	Sand Muskogee Timber Ridge	20 12 10	Subsurface folding	150 150 150	
Josey.............	Okfuskee	2980	Lyons	50	Local anticline	25–190	
Kellyville.........	Creek	1560 2010 2140 2450 2800	Oswego Red Fork Glenn Dutcher Mississippi	30 30 40 30 40	Anticlinal folds	20–30 10–100 10–50 50–200 10–40	1–8 1
Kendrick or Skellyford............	Lincoln	2500	Prue	40	Local variations from monocline	Oil	1
Keystone..........	Pawnee	1100 1250 1800 1970 2525	Cleveland Oswego Skinner Mississippi Wilcox	45 60 20 55 10	Minor folds	4–100 10–85 Oil 30–60 Show	1–6 1–2
Kiefer............	Creek	1850 1990 2100 2600	Red Fork Taneha Dutcher Wilcox	20 20 50 10	Anticlinal folds	10–60 15–100 50–90 10–50	 1–30 1 1–3
Kilgore...........	Grady-Stephens	1725 1850 1990 2200	 Pontotoc (?)	25 30 10 10	Faulted anticline	30–200 20–200 Oil 50–500	1–5 11–42

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Knox..............	Stephens	1706	Pontotoc	50	Anticline	50–200	
		2099	(?)	10		50–100	
Kusa.............	McIntosh	1800	Dutcher	25	Local variations from dip	50	
Landon...........	Osage	1660		50	Minor folds	10–50	
		1770	Peru	20			1
						Oil	
		1950	Oswego	15		15–25	
		2890	Bartlesville	10		15–40	5
Lauderdale........	Pawnee	1185	Layton	15	Local variations in dip	25	
		1611	Cleveland	50		50	
		2275	Skinner	25		10–25	
		2350	Bartlesville	25		70–100	2
		2450	Wilcox	30		25–600	
Lawton...........	Comanche	161–180		10	Flat dome	1–3	
		244–255		13		2–6	
		380–400	Uncorrelated	20		1–5	1–2
		800–1000		50		5–10	
		1250		30		Show	
Lenapah..........	Nowata	940	Bartlesville	35	Minor folds	1–60	
Leonard..........	Tulsa	1220	Layton	10	Local folds	60–100	
		1430	Red Fork	20		3–120	
		1500	Bartlesville	22		10–150	1–17
Link..............	Muskogee	2044	Sand	8	Probable fault	90–100	
Little River.......	Seminole	2750	Chattanooga	20	Probable subsurface structures	50–120	
Loco.............	Stephens	850	Glenn	10	Loco anticline	Oil	
		980		5		1–15	
		1550		15		1–5	
Lyons-Quinn.......	Okmulgee	1820	Deaner		Lyons dome	Oil	
	Okfuskee	2600	Lyons	25	Quinn dome	50–700	
Madalene.........	Osage	1900	Bartlesville	35	Anticlinal folds	10–30	
Madill...........	Marshall	402	Trinity (Base)		Madill anticline	5–20	
Magnolia..........	Stephens	2000	Smith	44	Buried structure	Oil	
		2100	Brown	30		Oil	
		2200	Blaydes	27		10–400	
		2300	Kagay	85		25–100	

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production Oil, Bbl.	Initial Production Gas, M. Cu. Ft.
Major	Okmulgee	1255 1640 1750	Uncorrelated	30 20 10	Local folds	29–40 10–400 20–100	 2–5
Manion	Osage	1808 2190 2300	Oswego Bartlesville Burgess	17 30	Dome	12–200 Oil 50–400	2–5
Mannford	Creek	1550 1750 2230 2380 2980	Layton Oswego Skinner Bartlesville Wilcox	20 40 70 10	Terraces	Oil Oil Oil Oil 80–600	 1–6 Gas 1–3
Maramac	Pawnee	2070 2400 2650 2750 2900	Layton Cleveland Oswego Prue Skinner	50 60 70 60 40	Folds	Oil 15–100 Oil Oil 45	 10
March or Amabel	Payne	1975 2470 2650 2760	Layton Cleveland Oswego Prue	20 30 40 95	Local anticlinal folding	Oil Oil Oil 10–60	
Maud	Pottawatomie Seminole	2950	Uncorrelated		Folding and faulting	Oil	
Mervine	Kay	1000 1250 1500 1800	Mervine Hoover Endicott Stalnaker	25 15 13 22	Dome	20–400 10–400 50–250 5–40	
Micawber	Okfuskee	2430	Wheeler	10	Local folds	Oil	
Midwest	Okfuskee	2960	Deaner	70	Local folds	20	1–12
Milroy	Stephens	340–370 580 1060	Permian Unconformity Glenn	10 5 25	Elongated dome	Oil 20–40 10–35	1–4
Mission	Wagoner	1495 1840	Tyner Burgen	10 20	Fault	30–300 15–150	1–5
Morris	Okmulgee	450 700 1200 1300 1600 1725 1800 2000 2450	Stray Salt or Glen 1st Booch 2d Booch Morris Glen of Morris Fields Lyons-Quinn Wilcox	25 150 20 25 20 25 10 25 45	Anticlinal folds	10 Oil 10–3000 10–200 20–300 15–75 10–150 25–200 60–300	 Gas

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Morrison or Watchorn.......	Pawnee	2690	Layton	30	Subsurface folding	15–500	
Mounds...........	Creek	1100	Red Fork	20	Substructure folds	Oil	
		1480	Glenn	170		20–300	1–4
		1650	Tucker	20		Oil	
		1850	Taneha	45		Oil	
		2050	Dutcher	55		100–2000	1–3
		2400	Wilcox	30		35–1000	
Muskogee.........	Muskogee	1052	Uncorrelated	20	Folding and faulting	5–50	
		1137		10		10	
		1260		30		100–500	
		1400	Muskogee			40–80	
		1600	Uncorrelated	15		25–120	
		1790		15		1–20	
Myers Dome......	Osage	2400	Burgess	40	Myers Dome	4–150	
Natura...........	Okmulgee	1730	Glenn of Morris	10	Anticlinal folds	10–60	
		2755	Wilcox	10		60–150	
Nelagoney.........	Osage	1400	Bartlesville	60	Anticline, faults	15–300	
New Cushing......	Payne	2000	Layton	20	Subsurface folding	Oil	
		2400	Cleveland	30		Oil	
New York.........	Creek	1850	Glenn	150	Local anticlinal folds	10–100	
		2200	Dutcher	300		20–200	
		2850	Wilcox	50		Oil	
North Baltimore...	Okfuskee	2470	Deaner	40	Subsurface folds and faults	50–300	4–11
		2610	Lyons	20		10–300	
Nowata-Claggett...	Nowata	300(?)	Big Lime	20	Folding	1–10	
		600(?)	Oswego	30		20–180	
		950	Bartlesville	30		20–180	
		1350	Burgess	20		10–50	
Oak Grove........	Wagoner	785	Pitkin	30	Monocline, small dome	20–200	
		1190	Burgen	4		Oil	
Ochelata..........	Washington	690	Prue	20	Local folds	20–40	
		1185	Bartlesville	20		15–60	
Oglesby...........	Washington	985	Bartlesville	15	Minor folds	25–50	1–2

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Oilton	Creek	1480 2250 2700 2830	Layton Wheeler Bartlesville Tyner	20 70 90 15	Dome	10–25 10–50 50–5000 10–75	 1 1
Okay	Wagoner	550	Dutcher	60	Surface, two domes	1–10	
Okemah	Okfuskee	2970	Deaner	70	Subsurface anticline	100–400	
Okesa	Osage	1095 1527	Peru Bartlesville	75 17	Domes, anticlines, faults	Oil 20–600	
Okfuskee	Okfuskee	2660	Dutcher	50	Noses	50–300	
Oklahoma-Central	Okmulgee	1800 2091 2500	Glenn Taneha Dutcher	12 15 35	Subsurface dome and fault	30–250 10–100 300–1000	 5–20
Okmulgee	Okmulgee	1240 2000 2400	Bartlesville Booch Dutcher	75 10 35	Terrace noses	25 25 15–300	 2–9 1–5
Olean	Okmulgee	2075 2660	Dutcher Wilcox	25 70	Subsurface dome	20–100 15–150	1–5
Olive	Creek	1300 2330 2560 2730	Layton Skinner Bartlesville Tucker	15 30 70 110	Anticline and fault	10–50 3–100 50–6000 10–75	 2–10
Oneta	Wagoner	1000 1200	Dutcher		Four small domes on a large anticline	10–1300	
Osage city	Osage	1620 2250 2431	Cleveland Bartlesville Mississippi	25 30 30	Anticlinal folding	10–100 20–75 Show	 1–3
Oscar or Hampro	Jefferson	1180 1270 1320 1430 1500 1610	Glenn	18 20 35 30 30 15	Anticlinal axis	10–200 25–220 150–600 200–2000 30–500 10–60	
Otstot	Kay	2350	Stalnaker	40	Anticlinal folds	10–100	10–40
Owasso	Tulsa	1170 1360	Bartlesville Burgess	30 40	Local folds	10–175 10–30	3

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Paden	Okfuskee	2790 2890	Prue Bartlesville	10 200	Terraces and faults	10–60 90–150	
Pawhuska	Osage	2085 2125 2880	Bartlesville Burgess Burgen-siliceous	60 25 26	Anticlinal folds, faults	60–100 10–50 100–600	10–50 25 1–8
Pearsonia	Osage	2100 2410	Oswego Mississippi lime	100 40	Dome and anticlinal folds	Oil 20–2200	10
Pemeta	Creek	2330 2560 2730	Skinner Bartlesville Tucker	30 70 110	Dome	3–100 50–8000 10–200	
Perry	Noble	1805	Ragan	100	Nose	5–15	
Pershing	Osage	1385 2033	Cleveland Bartlesville	15 30	Dome	30 100–500	
Peterson	Muskogee	1208–1315	Sand	10	Folds, fold faults	25–950	
Pettit	Osage	800 1390 1800 1950 2300 2600 2650	Stray Cleveland Big Lime Oswego Bartlesville Hominy Siliceous	10 20 20 60 30 50	Domes, folds, faults	15 10–20 20–90 5–60 20 50 75–6000	
Phillipsville	Okmulgee	2250 2750	Dutcher Wilcox	30 40	Subsurface domes	10–200 50–2000	
Pollyanna	Okmulgee	1840 2285 2830	Glenn Taneha Wilcox	40 20 10	Subsurface structure	20–300 20–75 Oil	6–10 15–35
Polo	Noble	2075 2260	Garber Covington	30 5	Noses	15 20	
Ponca City	Kay	1500 2100	Hoover Tonkawa	30 30	Anticlinal folds	40–150 20–200	
Poor Farm	Creek	2400 2800 2067	Prue Bartlesville Dutcher	75 60 10	Monocline	75–100 10–50 50–2000	

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Pond Creek	Osage	1235 1680	Peru Burgess	35 20	Anticlinal folding	10–50 10–100	
Porter	Wagoner	700 1422	Dutcher Burgen	110 10	Folding and faulting	Show 10–100	1–5 1–7
Prairie	Creek	1850 2200 2850	Glenn Dutcher Wilcox	150 300	Anticlinal folding	Oil Oil Oil	
Preston	Okmulgee	1400 1700 2020	Glenn or Salt Booch Dutcher	150 40 30	Local folds	10–50 15–25 25–1000	
Prue	Osage	1990	Bartlesville	50	Anticlinal folds and domes	30–50	
Pure	Creek	2385 2560 2800	Wheeler Prue Skinner	30 15 50	Minor folds	Oil Oil Oil	
Quapaw	Osage	1720	Bartlesville	60	Anticlinal nosing	25–75	
Quay	Pawnee-Payne	2490 2670	Oswego Prue	60 40	Folding, faulting	Oil 10–50	
Rainolá	Stephens	2000 2100	Smith Brown	25 55	Local folding	10–100 20	1–4
Ralston	Pawnee	2780	Oswego	20	Ralston anticline	Oil	
Ramona	Washington	934 1687 1753	Big Lime Bartlesville Burgess	100 20 20	Terraces, faults	10–60 45–500 10–50	1–5
Red Fork	Tulsa	599 1275 2160	Oswego Red Fork Turkey Mt.	30 25 15	Anticlinal folds	5–10 3–20 15–50	1 1–2
Riverland	Tulsa	1545 1698 2000 2120 2255	Taneha Burgess Wilcox Siliceous Turkey Mt.	30 10 12 36 20	Anticlinal folding	10–60 15 70–175 80–3000 30–2000	
Robberson	Garvin	1200 1877	Pontotoc Simpson	10 400	Anticlinal folding	5–200 10–600	
Robinson	Muskogee	1325	Muskogee	18	Folds	150–800	

Table 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Round Up	Carter	1025		5	Monocline under unconformity	30	
		1128		40			
Sageeyah	Rogers	525	Bartlesville	10	Local folds	1–25	
Salt Creek	Okmulgee	2430	Dutcher	10	Local folds	35–400	
		2575	Youngstown	25		60–120	3–33
Sand Springs or Charles Page	Tulsa-Osage	1100	Oswego	35	Anticlinal nose	10–30	
		1750	Tucker	15		10–40	
		2177	Siliceous	10		35–1500	
Sapulpa	Creek	1000	Perryman	30	Anticlinal folds	10–30	
		1365	Glenn	40		2–100	
		1635	Taneha	10		15–40	2
		1835	Dutcher	10		25–250	1–3
		2290	Wilcox	5		25–40	5–9
Sayre	Beckham	2775	Pontotoc (?)	50	Subsurface dome	200	1–12
		2995		10		50–200	10–70
Schulter	Okmulgee	1962	Glenn	40	Local structure	40–400	6–10
		2290	Deaner	20		Oil	
Scott	Creek	2340	Taneha	10	Local folds	10–30	
		2510	Dutcher	20		50–1200	10
Seltzer	Wagoner	800	Dutcher	20	Faulting	6–300	1–5
Shamrock	Creek	2200	Wheeler	25	Shamrock dome	50–300	
		2700	Bartlesville	50		250–2000	
		2800	Tucker	20		100–1000	
Sheppard	Muskogee	1940–1968	Sand	20	Subsurface folds	50–600	
Skiatook	Osage	1370	Bartlesville	20	Two domes	20–100	
		1460	Burgess	10		10–30	
		1500	Mississippi	150			1–3
Slick	Creek	2340	Glenn	260	Anticlinal folding	50–500	
		2620	Dutcher	45		200–1050	10
Sommerville	Muskogee	1439	Sand	11	Subsurface folds	375	
South Coffeyville	Nowata	120		1–10	Reverse dips	2–6	
		140	Squirrel	30		1–2	
		820	Bartlesville	15		2–25	
		920					

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
South Elgin	Osage	855	Ramsey	5	Folding and faults	40–75	
		900	Peru	160		25–200	
		1150	Oswego	10		2–5	
Spencer	Okmulgee	1285	Red Fork	20	Subsurface folds	6–15	
		1312	Dutcher	100		10–200	1–2
Sperry	Tulsa	1150	Bartlesville	65	Local folds	5–75	3–25
		1290	Taneha	10		10–100	
		1335	Burgess	10		5–25	1
		1440	Mississippi	20		15	
		1760	Tyner	40		10–400	1–6
Stone Bluff	Wagoner	1800–2000	Misener		Local folds	50–400	
		1985–2100	Burgen			35–60	
Striker	Wagoner	450	Dutcher Series	5	Faulting	10–15	
		800		20		6–30	
		915	Morrow-Pitkin	10		10–150	
Stroud	Creek-Lincoln	2490	Prue	6	Anticlinal folding	5–25	
		2555	Skinner	30		15–25	
Summers	Muskogee	1443	Sand	12	Subsurface folds	50–800	
Sunray	Tulsa	1000	Perryman	35	Local folds	5–10	1
		1320	Red Fork	10		5–25	
		1466	Taneha	34		40	1–2
		1570	Burgess	30		10	1
		1975	Wilcox	25		10–290	1–4
		2170	Turkey Mt.	20		10–400	
Taneha	Rogers-Tulsa	1322		20	Local folds	3	1–7
Tatums	Carter	2320		3	Local folds	90	
		2350		20		300	
		2380		15		95	
Terra-Okla	Muskogee	1744–1789	Sand	9–22	Subsurface folds	75–1400	
Terlton	Pawnee	1460	Layton	45	Terraces	10–15	
		1960	Cleveland	35		5–10	1
		2355	Wheeler	30		20–125	
		2580	Skinner	24		10–100	
		2680	Bartlesville	70		10–1500	
		2811	Tucker	14		15–75	
Thomas	Kay	1900			Faulted anticlinal folds	Oil	
		2055	Thomas			250	
		2600	Turk			Oil	

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production: Oil, Bbl.	Initial Production: Gas, M. Cu. Ft.
Tibbens	Creek	1290	Layton	10	Folding	10–40	
		2300	Wheeler	25		20–40	
Tiger Flats	Okmulgee	1515	Glenn	35	Folding	20–30	
		1900	Booch	25		30–570	1
		2300	Deaner	100		30–400	
		2590	Lyons	110		100–300	10
Tonkawa	Kay-Noble	1450	Newkirk	40	Faulted anticline	20–75	1–15
		1850	Middle Hoover	15		25–375	
		2000	Lower Hoover	50		35–300	1–10
		2050	Carmichael	50		15–1225	
		2100	Endicott	6		50	
		2500	Tonkawa	30		50–3000	1–6
Transcontinental	Muskogee	1863	Sand	15	Subsurface folds	50–100	
Tulsa	Tulsa	1086	Perryman	10	Local folds	10–15	
		1300	Red Fork	30		Oil	
		1446	Bartlesville	50		10–50	
		1990	Wilcox	20		10–100	1–2
Turkey Mountain	Tulsa	490	Big Lime	200	Dome folding	2–10	
		750	Oswego	20		2–10	
		1390	Red Fork	10		5	
		1452	Glenn	70		1–40	1
		1950	Dutcher	30		Oil	1–4
		2090	Wilcox	30		10–200	
		2145	Turkey Mountain	30		5–1000	1–5
Turley	Tulsa	1260	Bartlesville	45	Folding	10–40	
		1945	Siliceous	20			2–12
		1945	Siliceous	20		60–500	1–5
Tuskegee	Creek	2660	Taneha	40	Faulting	10–80	
		2810	Dutcher	50		5–75	
Velma	Stephens	350–900	Permian		Anticline	5–50	1–5
		1700–2300	Glenn			25–50	
Vera	Washington	1350	Bartlesville	40–60	Local folds	100–300	
Vernon	Kay	2300	Tonkawa	30	Dome	100–200	5–10
Vinita	Rogers-Craig	400	Burgess	50	Local dips	3–10	1–2
Vines	Murray		Simpson		Dome	1–2	
Wagoner	Wagoner	200–360	Dutcher		Subsurface folds	10–145	1–3
		650–800	Tyner			10–20	

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Wainright	Muskogee	1910	Sand	20	Subsurface folds	100–600	
Walters	Cotton	2100	Priddy	10	Anticline and dome	20–200	1–3
		2200	Keys	50		10–100	
Wann	Nowata	1000	Bartlesville	50	Monocline	10–40	
Webb	Grant	2940	Tonkawa	10	Local folds	100–400	
Webster	Wagoner	1160	Burgen	30	Local folds	30–300	
Weleetka	Okfuskee	2530–2660	Gilcrease	30	Various folds	10–200	1–15
Wetumka	Huges	2900	Deaner	30–50	Faulting	50–600	
Wewoko	Seminole	1843		20	Subsurface folds and domes	60–100	
Wheeler	Carter	960	Uncorrelated	40	Wheeler dome	5–70	
		1024		20		10–235	
Wicey	Tulsa	1480	Glenn	60	Local folds	2–100	
		1650	Taneha	50		25–100	1–3
		1950	Dutcher	52		10–300	
Wimer	Craig	700	Burgess	40	Monocline	20	1–3
		1040	Wilcox	20		Show	
Wilcox	Okmulgee	2672	Wilcox	15	Domes	100–1400	
Wild Cat Jim	Carter	1552		8	Buried anticlinal fold	10	
		1646		26		70	
		1673		15		60	
		1690		32		110	
		1735		10		70	
		1836		30		142	
		1990		32		40	
		2285		16		13	
		2378		8		82	
		2447		51		100	
		2505		15		15	
		2672		63		35	
		2890		15		40	
Wildhorse	Osage	1150	Cleveland	100	Folds and domes	6–20	
		1250	Oswego	55		20	
		1590	Skinner	50		10–50	
		1826	Bartlesville	110		100–7000	1–5
		1990	Burgess	10		50–500	
		2270	Tyner	25		10–100	

TABLE 2.—(*Continued*)

Field	County	Depth, Ft.	Sand	Thickness, Ft.	Structure	Initial Production	
						Oil, Bbl.	Gas, M. Cu. Ft.
Wiser	Osage	750 1700	Wayside Burgess	20–25 10–12	Folds and anticlines	10–60 10	
Woolsey	Stephens	1750	Glenn	100	Anticline and fault	25–130	
Wynona	Osage	1600 1745 2088 2281	Pery Oswego Bartlesville Mississippi	25 60 20 20	Domes	20–50 10–30 25–500 35–275	1–9 1–17
X686	Osage	1110	Cleveland	30	Anticlinal folding	40–80	
Y686	Osage	1385	Peru	10	Dome and anticlinal folding	Show	
Yale	Payne	2865 2940	Oswego Prue	20 40	Anticlinal folding	25–50 45–100	 10–20
Yeager	Hughes	2790	Booch	50	Faulting and local folds	25–300	
Yahola	Muskogee	1220 1320	Booch Boynton	50 20	Anticlinal folding	40–500 25–180	1–3 1
Youngstown	Okmulgee	1860 2250 2400	Glenn Youngstown Dutcher	60 50 60	Subsurface anticlinal folding	15–100 100–300 75–1000	10–40

Therefore, considering only physical limitations, any sand that has favorable physical properties and a sufficient amount of oil may be flooded.

Data by which to make a general survey of the areas physically water-floodable in the Mid-Continent are not available until a great many cores have been analyzed.

Economic considerations likewise limit the areal extent of territory suited to water-flooding. Tables 2 and 3 list the oil fields of eastern Oklahoma and Kansas that produce from under 3000 ft. in depth. This depth was chosen arbitrarily as probably the maximum for which water-flooding could be considered during the next 10 years. These fields in Oklahoma produce from one or more of the formations listed in Table 4. The producing formations in eastern Kansas are listed in Table 5.

TABLE 3.—*Kansas Oil Fields Approximately* 3000 *Feet Deep or Less*

Atyio-Pixlee	Eastborough	Hanna	Peabody
Augusta	Eastman	Hazlett	Porter
Beaumont	Elbing	Horder	Potwin
Big Lake	Eldorado	Humboldt	Rainbow Bend
Bradfield	Edwards	Iola	Remple
Browning-Teeter	Elgin	Keighley	Robbins
Burkett	Elk City-Longton	Kontoul	Sedon
Bush City	Eureka	Lamont	Snowden
Bush Denton	Falls City	Leon-Blokemon	Sallyards
Chanute-Erie	Fox-Bush	Lost Springs	Sluss-Smoch
Cherryvale	Frankhouser	McClaskey	Starr
Churchhill	Fredonia-Benedict	Monticello	State
Climors	Gaffney	Moron	Toronto-Webb
Coffeyville	Garnett	Neodesha	Tyro
Colony	Gilroy-Quiney	Neosho-Falls	Virgil
Covert-Sellers	Grand Summit	Olsen-Podgett	Wech-Fromm
Davis	Greenwich	Oxford-Carson	Weirshing
Demalorie	Goodrich	Paloa	Woyside Bolton
Dexter			Young

The Bartlesville sand has the greatest areal extent of any of the productive formations in eastern Kansas and northeastern Oklahoma. Bartlesville sand probably contains the largest recoverable reserve as measured by the potentialities of water-flooding. Typical core analyses, presented later in this paper, show the formation in many localities to have physical conditions favorable to water-flooding. The areal distribution of the Bartlesville sand in northeastern Oklahoma is shown in Fig. 1.

RESERVES IN FLOODABLE AREAS

To arrive at some idea of the oil reserves of this area, the areal extent of the fields as shown on the nomenclature map of the Mid-Continent Oil and Gas Association was approximated by tracing the edges of the productive regions with a planimeter. The results should be conservative, since there are many small productive zones not shown on the map. A productive area of 600,000 acres for eastern Kansas and 800,000 acres for northeastern Oklahoma was obtained by this method. The various producing sands in these areas were assumed to average a theoretical sand of 15 per cent porosity, 35 per cent saturated with oil, and 20 ft. thick; in other words, a sand containing 8000 bbl. of oil per acre. Consequently the oil content of the producing regions under 3000 ft. in depth in eastern Kansas is estimated at 4,800,000,000 bbl. and in northeastern Oklahoma at 6,400,000,000 bbl. This considerable volume of oil remaining in the sands at the present time, properly speaking, is not a reserve. *Only the recoverable portion is a reserve.* If the whole acreage were found to be suitable for water-flooding by criteria discussed in this paper, a

reasonable recovery, and hence a *reserve*, of 3,000,000,000 bbl. should be expected.

Core Analyses

In an appraisal of the possibilities of water-flooding to a particular field, and in the development of each project therein, the taking and analysis of cores from the producing sand plays an important role. The

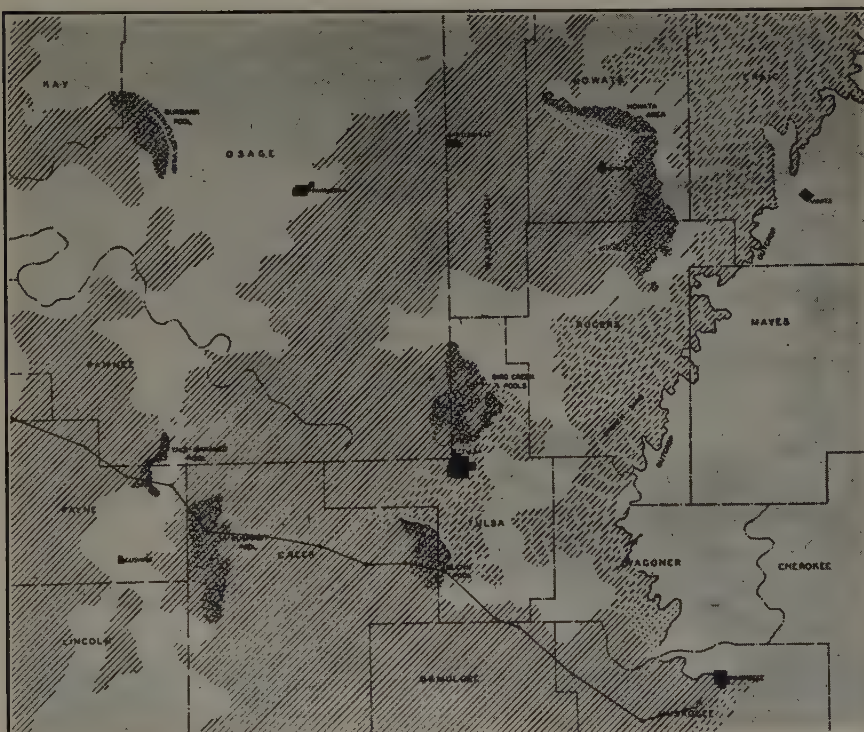

Fig. 1.—Areal distribution of Bartlesville sand in northeastern Oklahoma (*after Snow*).

Area included is approximately 100 miles from north to south and 115 miles from east to west. Where well-log correlations show the sand to be a continuous body the sand is shown by continuous lines; where the sand is very thin or broken, by dashed lines; and, where absent, by blank spaces. The principal oil-bearing areas are shown by dots between the lines. There are localized areas producing from the Bartlesville sand that are not shown on the map.

cores are analyzed in the laboratory to obtain information concerning the porosity, permeability and oil content of the sand. Reliable methods of analysis for these properties have been established through research and standardization. Many of the larger oil companies in this area maintain well equipped laboratories for this purpose. For the smaller operator, as well as for those that do not wish to equip a laboratory, reliable commercial laboratories exist in which this work is a specialty. So valuable

TABLE 4.—*Producing Horizons, Northern Oklahoma*

Age	Formation	Correlation
Permian	Hoy	
	Kisner	
	Hotson	
	Blackwell	
	Newkirk	
	Grayhorse	
	Upper Hoover	Hoover Series
	Middle Hoover	Hoover Series
	Lower Hoover	Hoover Series
	Elgin	
	Musselman	
	Carmichael	
	Endicott	
	Tonkawa	Ponca, Stalnaker; Swaggert, Jones
	Layton	
	Cleveland	
	Big Lime	
	Peru	
	Oswego	Wheeler, Ft. Scott
	Prue	Bixler, Squirrel, Perryman
	Red Fork	Skinner
	Bartlesville	Burbank,[a] Salt sand, Glenn
	Tucker	Booch, Taneha, Boynton
	Doggett	
	Smith	
	Sykes (Dutcher Group)	Gilcrease, Youngstown
Mississippi	Deaner	
	Lyons	Lyons lime, Pitkin lime
	Burgess	Quinn, Cromwell, Papoose
	Mississippi lime	
	Chattanooga	
	Misener sand	Sylamore sand
Siluro-Dev.	Hunton lime	
	Sylvan shale	
Ordovician	Viola lime	
	Wilcox	
	Tyner	Simpson formation
	Burgen	
Cambro-Ord	Siliceous lime	Arbuckle, Turkey Mt. sand

[a] Burbank is not Bartlesville, but is found at that horizon.

TABLE 5.—*Producing Formations in Eastern Kansas*

System	Formation	Member	Horizon and Where Productive
Pennsylvanian	Wabaunsee	Eskridge shale Neva Elmdale shale Americus	
		Admire shale	550-ft. and 660-ft. sands at El Dorado gas sand, Cowley County.
		Emporia Willard shale Burlingame	
	Shawnee	Scranton shale Howard limestone	990-ft. gas sand at El Dorado. Highest "pay" at Oxford.
		Severly shale Topeka limestone Calhoun shale	Good shows at Oxford, Churchill, etc. 1125-ft. gas sand at El Dorado, etc.
		Deer Creek Tecumseh shale Lecompton Kanwaka	1200-ft. gas sand at El Dorado, etc. Elgin and Hoover sands.
		Oread Lawrence	1475-ft. gas sand at El Dorado, etc.
		Iatan Weston shale	Boyer oil sand at El Dorado, etc.
	Lansing	Stanton limestone	Oswald lime in Russell County pools, etc. Stalnaker sand at Oxford, etc.
		Vilas shale Plattsburg Lane shale	Lower "pays" at Fairport and Russell Counties.
		Iola limestone Chanute shale Drum limestone	Encill sand of Elk County. Stokes oil sand at El Dorado, etc.
	Kansas City	Cherryvale Winterset Galesburg Bethany Falls Ladore shale	Layton sand.
		Hertha limestone	Gas sand of Elk County.
	Marmaton	Dudley shale Lenapah limestone Nowata shale	Old Red sand of Chautauqua and Elk counties. Peru sand of Montgomery, Elk, and Chautauqua counties.
		Altamont Bandera shale	Weiser sand of Montgomery and Chautauqua counties.

TABLE 5.—(*Continued*)

System	Formation	Member	Horizon and Where Productive
Pennsylvanian	Marmaton	Pawnee Labette shale	Peru sand in some places in southeast Kansas.
		Fort Scott limestone	Oswego lime of Elk, Chautauqua, Wilson, etc.
	Cherokee		Shoestring sands of Linn, Anderson county. Bartlesville sand of Greenwood, Butler, Cowley, etc. Trends of Greenwood County, etc.
			Various horizons in Bourbon, Butler, Elk, Franklin, Labette, Lyon, Miami, and Neosho counties.
			Burgess sand in Chautauqua, Elk, and Montgomery.
	Pennsylvanian basal conglomerate of varying age-Welch chert in part. Gorham sand (western Kansas).		
Mississippian	Osage	Boone	Mississippi lime in south central Kansas. Chautauqua, Elk, Greenwood, and Montgomery. Welch chert in part.
	Kinderhook	Chattanooga	First break, basal sand, Misener of Oklahoma.
Ordovician	Viola lime		Viola lime or second break in lime of south central Kansas. Viola production in Marion County, etc. Sometimes called "Leon lime."
	St. Peter or Wilcox		Wilcox sand. Sumner County, Sedgwick, etc. Stapleton zone of El Dorado in part.
	Arbuckle		Siliceous lime of granite ridge and Cowley County. Stapleton zone of El Dorado in part. Produces in Graham pool and in Elk County.

have core analyses become, not only in water-flooding and appraisal of stripper properties but also in all production practice, the tendency is to take more cores more carefully than ever before and to have all cores analyzed thoroughly.

The relationship of the three tests usually performed on cores—measurement of porosity, permeability and oil content—and some of the uses to which the data are put are shown graphically in Fig. 2.

It is evident that no one test is more important than the others, since they are interdependent. Also, after studying the chart, it seems strange that only recently has permeability been a part of core analysis. Three years ago only two or three laboratories in the country were equipped to make permeability tests; one in a university and none in commercial laboratories.

Mid-Continent Cores

Although comparatively few cores have been taken and analyzed from the area under discussion, some results are available in Table 6.

Best results have been obtained in this area with diamond-drill cores and the majority of the cores tabulated were of this type. The results are not to be considered as typical of the area until more information proves them to be representative. Indeed, these few data indicate that a considerable variation in the properties of Mid-Continent cores can be expected. Furthermore, it must be remembered that the data in Table 6 are averaged for each core from analytical results on as many individual samples as possible. Properly, the detailed analysis illustrat-

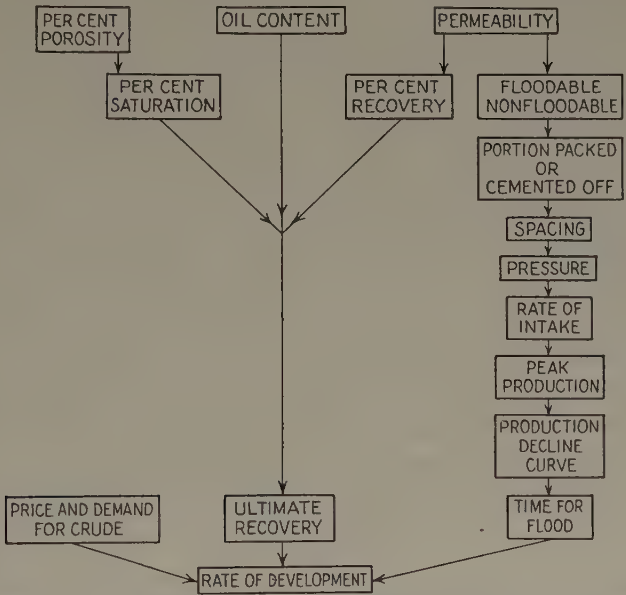

FIG. 2.—LABORATORY ANALYSIS OF OIL-SAND CORES. *(By James A. Lewis, Petroleum Reclamation Co., Bradford, Pa.)*

ing the variation in porosity, permeability and oil content with depth should be presented, together with stratigraphic variation such as shale and lime breaks. These data are presented best in graphic form as profiles. Limitations of space forbid such elaboration in this paper. In studying the analytical results for a core the profiles always should be prepared.

Although few in number, the data in Table 6 are consistent with logic. For example, it is logical that in general in this area oil saturation should vary inversely with permeability, and the data so indicate. This relationship would not be expected to hold necessarily at low permeabilities. Assuming that gravity is an indication of the viscosity of crude oil in this area, it would be expected that residual saturation is higher, other things being equal, the lower the gravity (higher viscosity) of the crude. Meager evidence presented in the table confirms this view. Obviously, too, there is no simple relation indicated between porosity and permeabil-

TABLE 6.—*Analyses of Cores from Mid-Continent Wells*

No.	State	County	Sand	Depth,[a] Ft.	Thickness, Ft.	Porosity,[b] Per Cent	Permeability,[b] Millidarcies	Saturation,[b] Per Cent	Oil Content, Bbl. per Acre	Gravity, A.P.I.
1	Okla.	Rogers	Bartlesville	380	47	14	18	47	24,000	34
2	Okla.	Rogers	Bartlesville	364	28	19	12	50	20,000	34
3	Okla.	Rogers	Bartlesville	372	40	17	26	36	19,000	34
4	Okla.	Rogers	Bartlesville	446	30	10	2	30	7,000	32
5	Okla.	Rogers	Bartlesville	392	20	10	1	45	7,000	32
6	Okla.	Rogers	Bartlesville	350	34	17	24	44	20,000	34
7	Okla.	Nowata	Bartlesville	471	33	18	20	21	9,500	34
8	Okla.	Nowata	Bartlesville	480	37	11	8	38	12,000	34
9	Okla.	Nowata	Bartlesville	618	25	23	250	65	25,000	36
10	Okla.	Nowata	Bartlesville	608	46	20	180	40	27,000	36
11	Okla.	Nowata	Bartlesville	607	26	20	170	40	16,000	36
12	Okla.	Nowata	Bartlesville	635	23	20	125	46	17,000	35
13	Okla.	Nowata	Bartlesville	603	10	21	140	31	9,000	35
14	Okla.	Nowata	Bartlesville	608	25	18	175	33	13,500	35
15	Okla.	Nowata	Bartlesville	484	38	18	26	29	13,000	
16	Okla.	Nowata	Bartlesville	488	30	17	30	36	13,700	
17	Okla.	Washington	Wayside	494	9	16	20	36	2,300	32
18	Okla.	Osage	Bartlesville	1,661	50	26	1,000	20	20,000	
19	Okla.	Osage	Bartlesville	1,711	43	18	100	35	21,000	
20	Kansas	Montgomery	Wiser	779	45	15	5	10	5,000	30
21	Kansas	Chautauqua	Peru	1,100	25	17	25	24	8,000	30
22	Kansas	Allen	Bartlesville	819	30	20	70	45	20,000	30
23	Kansas	Greenwood	Bartlesville	1,969	63	22	48	16	15,300	42[c]

[a] Top of sand.
[b] Integrated average.
[c] Absolute viscosity at 70° F. = 4.5 centipoises.

ity. Cores 12, 13 and 14 typify an interesting situation. These cores are from a lease condemned during the period of initial development and flush production as having no oil, because several widely spaced "dry" holes were drilled thereon. It is evident from the analyses of cores from this property that the wells were relatively dry only because of a deficiency of energy in the sand and not because of a lack of oil. Possibly similar occurrences have been numerous. Surely here is a fruitful field for investigation.

Production Records

The production history of the properties from which these cores were obtained should be considered in drawing conclusions from the data. Unfortunately, this is difficult, if not impossible, to obtain in many cases. The properties represented by cores 1 to 6 inclusive probably have yielded about 3000 bbl. of oil per acre over a period of 30 years by natural production, use of vacuum and repressuring with air and gas. A property in this general area, but undoubtedly more prolific, for which complete records are available, has produced 5000 bbl. of oil per acre in 30 years by the same methods. The properties represented by cores 9, 10 and 11 have yielded nearly 12,000 bbl. of oil per acre in a comparable period of time. The lease from which core 23 was secured has produced 5200 bbl. of oil per acre in 10 years by simple pumping from the top of the sand. Other things being equal, within any one area, a useful criterion as to values is that the greater the past recovery by primary methods of production, the better the chances for success with flooding.

Natural Water-flooding

As mentioned previously, natural water-flooding has been practiced in Chautauqua County, Kansas, and other localities in the Mid-Continent for many years. Greater success has been experienced with this method in the Peru sand than with others. The methods that have been developed are simple, relatively inexpensive, but slow and uncertain in results compared to controlled flooding of any type. In some cases, it is true, profitable floods result; in others the results are dubious. As no core analyses are taken in using this method, and little control of a flood is possible, luck is a considerable factor in the results. Certainly no forecast of probable results is possible in using this method except for a limited area after considerable experience. In flooding the Peru sand by this method, casing is either pulled completely, or (better practice) is slit, cut or gashed opposite a water sand. The water from the Big Salt sand above the Peru is a favorite source of supply. Since the legalizing of water-flooding in Kansas, the more progressive operators are putting water in wells from the top of the casinghead and, in some instances,

even metering it. Oil wells are drilled in advance of the flood. As the flood passes, these in turn are converted to input wells. Usually the new wells are drilled about 300 ft. from the water wells. The result, of course, is a line drive. The effects of such a flood are noticed in from one to seven years from the time the water is added. Occasional oil wells produce as much as 15 bbl. per day at the peak for a period of from two to three years, but this is exceptional. A 5-bbl. well is considered a good one. The recovery made by one 100-acre lease in this area, first drilled 35 years ago, is available (Table 7). A body of sand on this lease

TABLE 7.—*Water-flooding of Peru Sand*

Year	Production, Bbl. per Year
1	4,421
2	2,171
3[a]	2,201
4	5,526
5	8,491
6	16,120
7	24,212
8	40,763

[a] Casing ripped.

thicker than usual for the area must be taken into account, and also that considerable drilling has been done each year to achieve these results. It should be remembered that the decline upon the cessation of drilling on this lease will be as rapid as was the increase.

On another lease of 300 acres in this area a natural flood was started 24 years ago. Seventeen years ago this lease was producing 60 bbl. per day; today it is producing 180 bbl. per day.

Controlled Water-flooding

The first systematic water-flood in the Mid-Continent was initiated in 1931 in the Alluwe field, Rogers County, Oklahoma, by a major company as an experiment. A five-spot system was used but an attempt was made to use the old wells. Experience proved this to be a mistake. The old wells were in poor physical and mechanical condition after 30 years of production. Also, the old logs of the wells, if existent, could not be depended on for information as to the correct depths of the various strata. It happened that there was a thief stratum in the sand that caused considerable difficulty. Trouble was experienced with by-passing, channeling and consequent waste of water, time and effort. In this shallow territory a new well can be drilled and equipped for so little more than the cost of reconditioning an old one that the obvious advantages of the new well allow no alternative.

The spacing used in this project is 440 ft. from like well to like well. An average of from 40 to 50 bbl. of water per day at a pressure of 400 lb.

per sq. in. is allowed each input well. The viscosity of the oil in this area is 13.24 centistokes at 70° F., and 7.88 at 100° F. The usual mechanical equipment for water-flooding is used. Input wells are completed in a different way from that used in the East. The wells are cased to the sand, the casing cemented and water put into the casing. Packers and tubing are not used. River water is used, treated and filtered to remove suspended matter and adjust the pH to proper alkalinity. The daily production of this lease was about 6 bbl. before water-flooding was begun; today it is maintained at 70 bbl. The gravity of the crude has been increased 2° A.P.I. Preliminary results would indicate that a recovery of between 3000 and 4000 bbl. per acre can be realized in from five to six years. The experiment has been hampered by the necessity for developing methods suited to Mid-Continent conditions, lack of suitable water supply at the beginning and numerous unexpected difficulties. Consequently the economics are not yet proved for controlled water-flooding anywhere in the Mid-Continent, although the physical success is. After methods are perfected, it would appear that development should not cost over $1000 per acre. If this is true, it would seem that even under present conditions water-flooding possesses possibilities.

The project represented by the properties from which cores 7 and 8 were secured has been developed in a similar way, except that delayed drilling of oil wells has been practiced. All old wells were plugged and abandoned. Water is obtained from shallow gravel beds, is aerated, treated with a coagulent and filtered before being used. A pressure of 450 lb. per sq. in. is necessary to inject from 35 to 70 bbl. of water per day per well, the quantity depending upon the thickness and permeability of the sand. The viscosity of the crude oil produced on this lease is 7.0 centistokes at 90° F. The spacing is 440 ft. from like well to like

TABLE 8.—*Water-flooding of Bartlesville Sand*

Month	Production, Bbl. per Month
1	275
2	200
3	270
4	260
5	535
6	675
7	1,550
8	[a]
9	[a]
10	2,480

[a] Figures not available.

well. Preliminary results of flooding on this lease are presented in Table 8.

Water was turned into the well represented by core 23 in May, 1935. This well is surrounded by four old oil wells. The project is purely experimental. The spacing is 660 ft. from like well to like well. Owing to the depth and permeability of the sand, hydrostatic head alone is utilized to inject the fluid. Water from a surface pond, treated with a coagulent and filtered, is used. The well required more than 500 bbl. a day at the start and still takes 300 bbl. per day. Recently the quantity of gas produced by the adjacent oil wells has increased. The quantity of oil produced by the four adjacent wells had increased 2 bbl. per day four months after the introduction of water. This is a remarkable increase considering the thickness of sand, short time of injection, wide spacing and the fact that only one input well is employed. Undoubtedly the saturation reported in Table 6 for this property is low. From the permeability and depth of the sand, together with the fact that the vertical permeability of the sand is virtually the same as the horizontal and the absence of shale breaks it is reasonable to suppose that considerable of the oil in the sand to be cored had been flushed ahead of the drill. It is being recognized that the problem of securing representative samples from a sand by coring is the most important one remaining to be solved in the field of core analysis.

An experimental project involving the flooding of 80 acres of shallow Bartlesville sand in Nowata County, Oklahoma, is also in progress. Delayed drilling will be employed. The interesting feature of this project is that the water to be used is the well known radium water (brine) of the region produced from about 1000 ft. below the Bartlesville sand. If the experiment appears to be successful, it will lead to the orderly development of at least 5000 acres held by the operating company.

Problems Peculiar to the Mid-Continent

In adapting water-flooding to conditions encountered in the Mid-Continent there are problems which either are not present in the East or require different solutions. There are two general types of problems: physical and economic. The success of water-flooding in this region depends upon their solution.

Physical Problems

Local sands usually are more permeable and possess a higher porosity, therefore it is not surprising to discover that oil saturation is lower than in the East in comparable cases, although not so low as to preclude profitable operation. Local sands are quite as uniform in permeability profile as those of the East, if not more so.

Crude oils are more viscous, higher in surface tension. This indicates more difficulty in removing oil from the sands, and more trouble to be expected with emulsions in water-flooding.

Supplies of good, fresh water are limited. A prolific, continuous supply of water on or near the property is required. Both surface and subsurface water can be considered, with quantity and continuity of supply being primary considerations. From 25,000 to 75,000 bbl. of water will be required for one acre over four to five years time. On a 40-acre tract the water requirements could reach 3,000,000 bbl., which would average about 1000 bbl. per day for the whole property. The water load, smaller during early development, will grow with development of a project. Each new set of water wells completed will require more water during the first period of injection than later.

The quality of the raw water available is not as serious a problem as the quantity. Poor water, of course, will introduce treating costs and increase handling costs, but the usual chemical treating and filtration methods are not expensive. The best fresh water in this area requires more treatment to suit it to flooding than in the East. If water-flooding comes into general use, salt waters must be used, as they are the only waters available in sufficient volume. Much remains to be learned regarding the treatment and economic handling of salt water. It must be treated to remove not only the constituents that would plug the sand but also render it substantially noncorrosive to pipe. Failing in the latter, corrosion-resistant pipe and casing must be used.

The analyses of several local waters (Table 9) illustrate the problems. In addition to the constituents that are listed in Table 9, some of the saline waters that are available in the necessary quantities contain dissolved carbon dioxide or hydrogen sulfide, or both. The removal of these gases is essential to economical handling of the waters.

Strata in this area are less firmly consolidated than in the East, therefore casing must be carried to the producing horizon to prevent caving. Because of this, and because of the difficulty of obtaining nonfrangible setting points for packers, it is probable that water wells will be equipped with cemented casing rather than with tubing and casing. An advantage of this practice is that it allows entry to the well and sand at any time for cleaning out. The casing is salvagable.

Economic

Mid-Continent crude sells for much less per barrel than eastern crude. It is possible that refining methods now coming into use will remove this disadvantage permanently. Drilling costs more per foot and per well than in the East. Various items such as wages, hours of work, ease of drilling and habit explain this. Completed wells cost more on a comparable basis, owing to the extra equipment necessary. Shooting costs more in the Mid-Continent than in the East for the same sized shot.

In addition to the solution of these problems, the usual factors of acreage, depth of sand, pipe line connections, topography and similar

items affecting costs soluble by usual engineering methods must be considered along with forecasts of the price of crude.

As an aid to the solution of these problems, it is suggested that, having ascertained necessary physical data and established costs and the probable price of crude, an economic analysis of the development of a unit of 1000 acres be made. This might be based upon, for example:

Year	Rate of Development, Percentage per Year	Rate of Depletion, Percentage per Year
1	5 (experimental)	25
2	15	25
3	25	20
4	25	15
5	20	10
6	10	5

Total time for depletion, 11 years.

By varying interrelated factors, the proper combination affording maximum profit is obtained.

It should be emphasized again that the water-flooding of oil sands is not foolproof. A proposed flood should be carefully studied and planned. The systematic water floods now in progress in the Mid-Continent were initiated only after detailed study of the condition of the sands had been made. This practice should be continued. If not, enthusiasm for a process promising profits will produce failures resulting in condemnation of it prematurely. Promiscuous dumping of water into oil wells should not be countenanced by regulatory bodies, engineers or executives.

To the casual observer of water-flooding in the East, the procedure and mechanics may appear relatively simple. Coring and core analysis may seem superfluous operations. However, contrary to the belief of many, a flood does not travel a uniform and fractional part of a foot per day in its progress through the sands. The unexpected can occur. In the East, for example, in extending a new line of five-spot oil wells on a 400-ft. spacing, the operator of a certain project, to his surprise and embarrassment, obtained nice water wells. The flood had passed despite precautions. With Mid-Continent sands of higher average permeability, the danger of a similar occurrence is enhanced; valuable reserves can be lost permanently if water is introduced without definite knowledge of the sand conditions.

Despite problems and difficulties, it is believed that a future awaits water-flooding in the Mid-Continent. This future depends on the solution of technical problems. If operations are conducted on a scientific basis and economic scale, the result should be that the interests of con-

TABLE 9.—*Analyses of Mid-Continent Waters*

Number State County Source Type	1 Kansas Chautauqua Big Salt Brine	2 Kansas Chautauqua Upper Fresh	3 Kansas Chautauqua Peru Brine	4 Kansas Montgomery Surface Fresh	5 Kansas Montgomery Wiser Brine	6 Kansas Greenwood Surface Fresh	7 Kansas Greenwood Bartlesville Brine[a]	8 Kansas Greenwood Bartlesville Brine[b]
			Parts per Million					
Ca	1,943	238	7,173	23	8,114	75	3,863	6,270
Mg	1,206	644	1,843	8	2,861	12	923	1,980
Na	15,471	1,360	39,674	33	21,633	14	29,800	50,600
Fe				0.1	19	0.1	42	23
(HCO_3)	305	433	226	79	159	34	28	29
(SO_4)	680	4,322	319	32	172	39	89	88
(Cl)	30,140	957	78,896	45	85,848	15	20,682	36,040
(SiO_2)				12	9		13	6
Total solids	49,745	7,954	128,131	232	88,815	189	55,440	95,036
pH				6.7	6.9	7.2	6.8	6.5

[a] Individual well.
[b] Composite, 12 wells.

servation will be served and the stripper well region will enjoy a prolonged economic life affording support to hundreds now dependent on the oil industry, values of stripper production will increase, capital will be attracted by dependable return on investments and a definite future to the Mid-Continent area can be planned and controlled. However, the process is no panacea for the economic ills of the region. Neither will it nor can it be relied upon to supply the oil required by the nation in increasing amounts. It cannot prevent inevitable shortage, but its use can be profitable and essential from the standpoints of conservation and economics.

Chemical Methods for Shutting Off Water in Oil and Gas Wells

By H. T. Kennedy*

(New York Meeting, February, 1936)

The fact that intrusion of water into oil wells can be prevented by treating the sand adjacent to the well seems to have been only recently recognized. Swan[1] mentions the process of solidifying naphthalene in strata. R. Van A. Mills[2] recommends the use of materials such as sodium silicate and sodium carbonate, which react with oil-field water to form solid plugging agents.

When a well is drilled in a new field the oil sands are found essentially devoid of water (Fig. 1). Unless a completely impermeable break exists

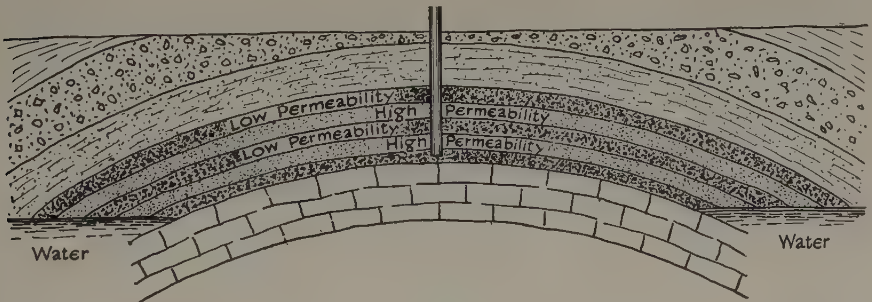

Fig. 1.—Water conditions when field is drilled.

over wide areas in the field, no water is found above the lower limit of the oil zone and no oil is found below the upper limit of the water zone. After considerable oil has been taken from the well, however, it is almost universal experience that water intrusion occurs. This intrusion may be of two kinds. The water may follow a path parallel to the bedding planes of the producing formation through loose streaks in the pay sand, as shown in Fig. 2, or the water level of the field may rise and enter the well by coning (Fig. 3). Water entering from the side is called "edge water," and that coming in from the bottom is called "bottom water."

Effectiveness of any method for shutting off water depends not only on the effective treatment of the sand adjacent to the well but on

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[1] U.S. Patent 1379657 (1921).

[2] U.S. Patent 1421706 (1922).

the geologic conditions of the sand. It is possible, of course, that oil and water, or gas and water, may enter the well through the same sand, although probably this is not a frequent occurrence. If this occurs, it is obviously impossible to shut off water without at the same time shutting off the flow of oil or gas, and no method of sand-treating can be effective.

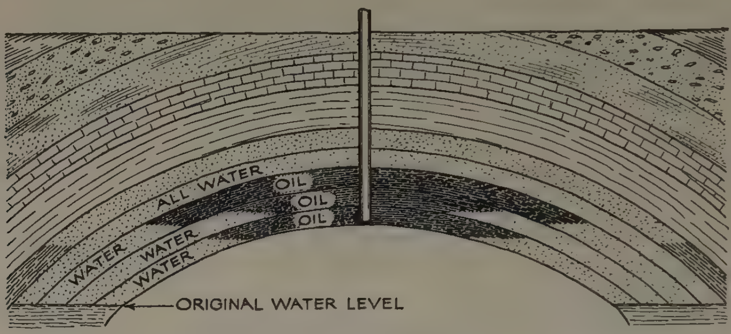


FIG. 2.—CONDITION AFTER EDGE WATER IS ENCOUNTERED.

Edge water can be completely shut off without in any way interfering with the flow of oil or gas. As a matter of fact, the flow of these fluids may be substantially increased by water shutoff, provided that essentially impermeable layers exist between the water-bearing strata and the strata bearing gas or oil, or that the vertical permeability of the sand is low compared to the horizontal permeability of the loose streaks.

The efficiency of any process for shutting off bottom water depends largely on the uniformity of the sand horizontally and vertically. The

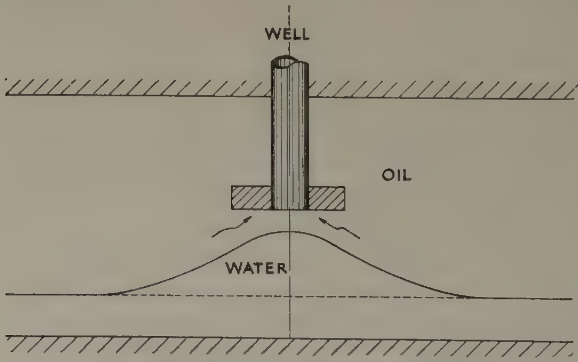


FIG. 3.—CONING OF BOTTOM WATER.

most unfavorable condition would be a perfectly homogeneous sand without shale breaks or other barriers. No sand of this nature has ever been found, but the condition may be approached in sands in which the shale breaks occur over very small areas, so that water may rise vertically between the breaks not far from the well. Even in these unfavorable

conditions, however, considerable reduction in water, or increase in amount of oil without water, can be accomplished. On theoretical grounds Muskat and Wyckoff have calculated that a disk 5 ft. in radius at the bottom of a well will increase the permissible oil production, without water, by about 40 per cent. If productive streaks of sand are separated by impermeable breaks, bottom water may be entirely eliminated by simply plugging with cement or lead wool, but these bottom plugs can be used only at the bottom of a well, and often pay sands exist below this level from which oil could be obtained by the use of chemical water shutoff, and deeper drilling.

Chemical water shutoff, as described in this paper, involves the formation of a precipitate in the pores of the water-bearing strata, by the use of chemicals that may be precipitated in water-bearing strata without at the same time affecting oil or gas-bearing strata. The effectiveness of a water shutoff treatment depends upon the amount of precipitate that can be formed in the pores, and upon the nature, especially the hardness, of the precipitate. If precipitating solutions are injected into both oil and water strata it is evident that precipitation must be avoided in the former, and in selective shutoff only one solution must be required, since in a method using two solutions injection and precipitation into both strata cannot be avoided. In this case, therefore, we are limited to the use of chemicals that will precipitate in contact with natural oil-field waters.

The bulk of the dissolved constituents in most water consists of sodium chloride, which cannot be precipitated by any ordinary reaction because salts containing sodium are all soluble in water, and because there is no commercial material that can be added to precipitate an insoluble chloride. The precipitable compounds of oil-field brines are thus limited to calcium and magnesium salts, which occur only in small amounts, seldom more than 1 or 2 per cent by weight. However, several materials are known which form voluminous precipitates on contact with water itself, and in which the volume of the precipitate is limited only by the amount of water available to react; among them, antimony trichloride, which in contact with water forms a voluminous precipitate of antimony oxychlorides. This material may be injected either in a concentrated water solution or dissolved in oil.

Silicon tetrachloride also reacts with water to form a voluminous precipitate of silicic acid, which in addition forms an effective cementing material to consolidate and strengthen the sand in the walls of the well.

There are several other materials that may be advantageously used, such as superfatted soaps, finely divided cements made up in nonaqueous suspensions, and colloidal solutions which on dilution or contact with salt water are precipitated, and form precipitates many times larger than may be obtained by any reaction involving chemicals dissolved in oil-field water.

Those not in direct contact with the water conditions involved in oil production will no doubt be surprised to learn that more water than oil is produced by the oil wells in the United States. As a matter of fact, for the 1,000,000,000 bbl. of oil, we annually produce about 2,200,000,000 bbl. of water. The lifting cost at 10¢ per barrel amounts to $220,000,000, a large part of which is avoidable. Table 1 shows the water-oil ratios for wells in different fields. This does not include water produced in gas wells, the lifting for which, per barrel, is much higher, since pumps must be installed for the sole purpose of lifting water. The elimination of the lifting expense is not the only advantage to be gained by shutting it off. When a nearly perfect shutoff can be obtained emulsion troubles and consequent expense of treating emulsions can be eliminated. Oil production and oil recovery per acre may be substantially increased by the utilization of the driving force of water, which in many cases is the primary source of energy in forcing oil from sand. In competitive fields many wells are found in which the daily production is limited by the capacity of the pump, and the water that is produced decreases the oil production by an equal amount. Also, many wells are abandoned because the lifting cost of water and oil cannot be paid for by the oil production. Often wells produce 95 to 99 per cent water, and the expense of handling the water rather than the shortage of oil production leads to their abandonment.

TABLE 1.—*Water-oil Ratios in Oil Wells*

Locality	Water to Oil Ratios		
	Pumping	Flowing	Total
Gulf Coast	4.1	0.13	0.9
Texas (exclusive of Gulf Coast)	3.2	2.4	2.7
Louisiana and Arkansas	14.3		14.3
Mid-Continent (Kansas, Oklahoma, N. Mexico)	2.4	0.1	2.1
Grand average	2.2		

Perhaps one of the most important applications of chemical water shutoff is in the saving of casing expense, especially in cable-tool drilling. Many casings are set for the sole purpose of preventing intrusion of water into the hole while drilling but frequently this function can be performed by an inexpensive treatment of the water sand by the proper application of the methods here described, and one or more strings of casing may be saved on each well.

The method of injecting chemicals into sand naturally varies with the condition of the well and equipment available. For a well pumping with fluid level substantially at the bottom, it is convenient to inject the

chemical through the casing without disturbing the pumping equipment, except to pack off the polished rod. It is desirable to remove all water from the hole by continuing to pump with standing valve set practically on bottom while 10 or 15 bbl. of oil are injected into the casing. This procedure allows the water to be removed without coming in contact with the chemical charge. If the chemical is soluble in oil, such as

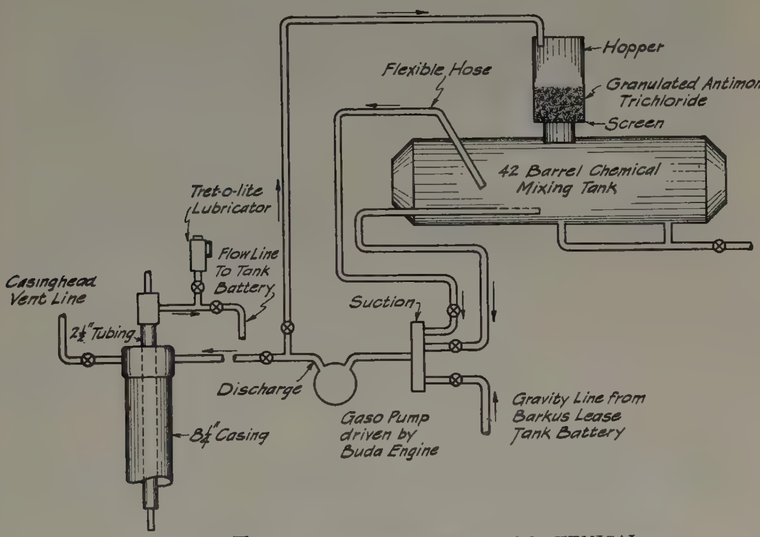


FIG. 4.—EQUIPMENT FOR INJECTION OF CHEMICAL.

FIG. 5.—WELL-HEAD CONNECTIONS FOR CHEMICAL INJECTION.

antimony trichloride or silicon tetrachloride, it is best to employ the oil solution directly following the oil, the amount to be used being determined by the thickness of sand to be shut off and the depth to which it is desired to penetrate. Experiments have shown that 1000 lb. of either of these chemicals is ample for 20 to 30 ft. of average sand, although it is evident that very loose sands require more than tight sands; also, that a chemical

like silicon tetrachloride, which forms a hard, voluminous precipitate, can be used more sparingly with good results than materials that are less effective for the purpose. After the chemical is pumped into the casing it is general procedure to apply an oil load, to make sure that the chemical is forced from the well into the sand. Fig. 4 shows the equipment used in

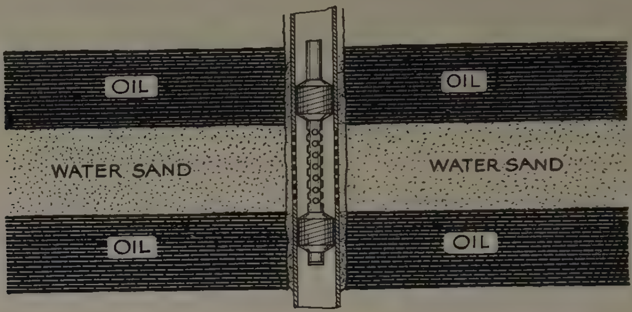


FIG. 6.—DOUBLE-PACKER METHOD OF INJECTING CHEMICAL.

mixing the chemical and pumping it into the well, and Fig. 5 shows the well-head connections on a well in the Seminole area to which this process was applied.

Although silicon tetrachloride and other chemicals of this class do not react in the absence of water, and therefore would do no harm to an oil sand, it is sometimes convenient, in order to avoid waste of chemical, to

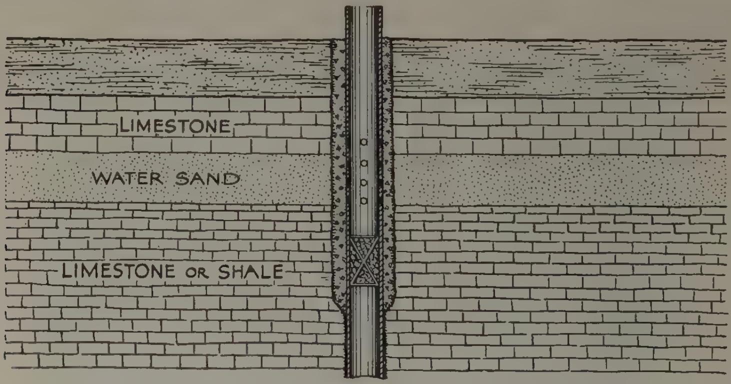
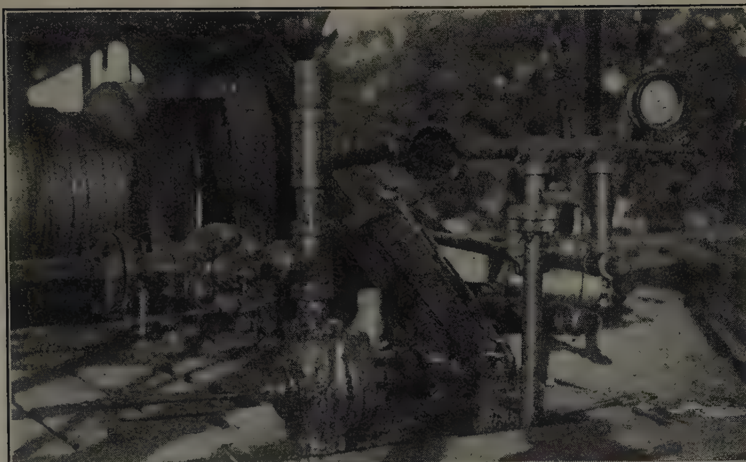


FIG. 7.—INJECTION OF CHEMICAL THROUGH PERFORATED CASING.

employ the double-packer method of treating sand (Fig. 6). This is done by setting an anchor packer near the top of the sand to be treated, and a hook-wall packer just below on tubing closed at the bottom and perforated between the packers. Water present in the tubing may be displaced by oil ahead of the chemical charge in order to avoid precipitates of the chemical in the well. This method has distinct advantages of economy of material, especially where the oil sand is more permeable than the water sand or where the pressure of the latter is high.



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FIGS. 8–10.—EQUIPMENT AND CONNECTIONS FOR CHEMICAL INJECTION ON A WELL IN CRESCENT FIELD, OKLAHOMA.

Fig. 7 shows the application of water shutoff method to a sand behind a string of casing, where the casing seat may be imperfect and thus cause leakage into the well, or where entry of water from one sand into another behind the casing is undesirable. Perforation of the casing can be conveniently accomplished by either a knife or a gun perforater.

When the fluid in the well cannot be pumped down to bottom, the injection of chemicals without mixing with water is somewhat more difficult, but can still be applied. Oil is pumped down the casing and up through tubing until returns of clear oil are obtained, the velocity of flow being great enough to carry the water up the tubing. The direction of flow is then reversed, the chemical being pumped down through the tubing until it reaches bottom. The casinghead is closed and sufficient pressure is applied through the tubing to accomplish the injection.

Figs. 8, 9 and 10 show the equipment and connections used for the purpose on a well in the Crescent field, Oklahoma.

Regarding the effectiveness of water shutoff treatments, it is evident that sand conditions have an important bearing. If water enters a well through cracks and crevices, only materials that set up to very firm cements can be effective, but if water enters the porous sand, as usually occurs, a perfect shutoff of water can be accomplished. One well making 25 bbl. of water per day before treatment was allowed to stand for five days after treatment without making a measurable quantity of water. In other wells shutoffs better than 99.5 per cent effective have been accomplished. A gas well in Pennsylvania was making 1000 gal. of water per day before treatment. The second month after treatment this well averaged 2½ gal. per day, which indicates that water shutoff by this method is both effective and permanent.

Acknowledgments

It is a pleasure to acknowledge my indebtedness to Dr. Paul D. Foote, Vice President and Director of the Gulf Research & Development Corporation, for encouragement in this work and permission to publish this paper; to Dr. B. B. Wescott; to Dr. W. P. Rand; to the Petroleum Engineering Departments of the Houston and Tulsa Production Divisions of the Gulf Oil Corporation of Pennsylvania; and to Mr. D. E. Conaway, of the United Natural Gas Co., for assistance in development of field technique in treating oil and gas wells.

DISCUSSION

(*T. V. Moore presiding*)

B. B. Cox,* New York, N.Y.—If it is necessary to shut off a flow of gas and water before oil is encountered in a boring, would it be necessary to use oil as the solvent of silicon tetrachloride or antimony trichloride to get the charge into the bore?

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* Producing Department, Socony-Vacuum Oil Co.

H. T. Kennedy.—The antimony trichloride has a peculiar property of being perfectly soluble with small amounts of water and, as diluted, becomes totally insoluble to form the oxychlorides. So that with antimony trichloride either water or oil can be used.

B. B. Cox.—I gathered from your paper that antimony trichloride did not form a hard precipitate that would support a friable sand. Therefore, as I understand it, it would seem necessary, in shutting off a heaving water-bearing sand, to inject a charge of oil in which silicon tetrachloride is dissolved.

H. T. Kennedy.—The silicon tetrachloride cannot be used with water. It does not have this property of being a clear solution with only small amounts of water. It has to be used with oil. It can be used with oil better than with antimony trichloride because it is soluble in oil proportions.

Member.—What does antimony trichloride cost?

H. T. Kennedy.—Five hundred pounds cost $80, which is small, compared with the other cost. Silicon tetrachloride costs from 10 to 15¢ per pound, depending on the quantity purchased. The cost of manufacturing this material is small and the price undoubtedly will be lower when greater quantities are used.

Member.—I understood you to say you needed to use the material you could remove in case you made a mistake. How do you remove it?

H. T. Kennedy.—I neglected to mention that with silicon tetrachloride you simply treat it with a caustic soda solution, provided, of course, you can get it in the sand. If you cannot get it in the sand or if it goes in very slowly, that may be a long job. Antimony trichloride forms the oxychlorides that may be removed by hydrochloric acid.

Member.—When the well is treated with silicon tetrachloride and it reacts with water, it must generate hydrochloric acid. Would that not react in the casing seats and cause trouble?

H. T. Kennedy.—Ordinarily it does not cause much trouble. As you probably know, a great many wells have been treated with much larger and much more concentrated shots of hydrochloric acid without an inhibitor. Of course, acid is not formed until the water is reached. That is one of the reasons we like to take the water out of the well in addition to plugging the well, but there is always some acid. If it is not absolutely 100 per cent shut off at first, there is some of the acid that comes back. But there is very little trouble from it because the amount of acid involved is really rather small. We get some pitting of valves, but at most it means the replacement of the valve.

Member.—Does the silicon tetrachloride precipitate in an oil sand if there is no water?

H. T. Kennedy.—No, only by action of the water. The reaction is

$$SiCl_4 + 3H_2O = H_2SiO_3 + 4HCl$$

It is only in contact with water that silicon tetrachloride changes form.

T. V. Moore,* Houston, Tex.—Mr. Kennedy, do you think there is any water in these oil sands?

* Humble Oil & Refining Co.

H. T. Kennedy.—Do you mean coming through with the oil?

T. V. Moore.—No, I mean intimately associated with the oil in the so-called oil sands themselves.

H. T. Kennedy.—Probably there is a small amount. However, one of the advantages of silicon tetrachloride is that a hard precipitate is not formed with small amounts of water. There must be an excess of water. I believe it figures out that about 7 or 8 per cent of water will not cause precipitation.

T. V. Moore.—I believe that with the amount of work that has been done on this problem we can look forward in a short time to being able to plug off all our wells exactly where and how we want to plug them, by simply pumping the proper mixture of chemicals down into the well. However, this process certainly must be used with care. We tried it once on one of our wells in Southwest Texas and we cut the water production of the well from 70 bbl. to 7 bbl. The only trouble was that we cut the oil production from 30 bbl. to about two barrels.

H. H. Power,* Tulsa, Okla.—I can go you the opposite on that, Mr. Moore. One of the wells that was treated in Oklahoma did not cut water production, but increased the oil production.

T. V. Moore.—I said "this method." I did not mean Mr. Kennedy's method, because it was a different method, but it had the same end in view, simply pumping down the right sort of mixture into the well and bringing the water well back into a nice pipe line oil well.

H. T. Kennedy.—Perhaps I should mention that we changed the water-oil ratio on one well we treated, before we had the advances we have now, from 2.2 to 0.7. As a matter of fact, we increased the oil production substantially, probably because of the mechanism I showed. If the water comes into a well without pushing oil ahead of it, it is essentially like a piston without any piston rings. It just blows by. If we start it off and increase pressures back where we want the pressure to push the oil in, we would expect to increase oil production.

E. A. Stephenson,† Rolla, Mo.—Probably you are familiar with some of the work done at Conroe; originally, I think, by Mr. Buck. Cement is pumped into the water sand below the oil sand, while a high pressure is maintained on the casing. The cement penetrates and seals the water sands at a pressure approximately half that required to penetrate the oil sands. This method has been used very successfully. It would be difficult to remove the cement by any known means if part of the oil sand were accidentally plugged and the production reduced; modern perforating devices will solve this problem.

Member.—What constitutes the charge?

H. T. Kennedy.—We have used various amounts. It depends largely upon the depth of sand we need to treat and upon the permeability of that sand. Loose sands naturally require more than tight sands. Sometimes we have treated sands that required only about half a drum of silicon tetrachloride. It was impossible to inject more chemical because it had completely sealed the formation. At other times we have used a drum. Sometimes we have used a charge of 1000 lb. of antimony trichloride, and sometimes 500 pounds.

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† Professor of Petroleum Engineering, Missouri School of Mines and Metallurgy.

Plug-back Cementing Methods

By C. P. Parsons,* Member A.I.M.E.

(Houston Meeting, October, 1935)

During the past year considerable interest has been shown in cementing operations for shutting off bottom water, whipstocking, etc. A number of plug-back methods have been used, with various adaptations for special conditions, but those described in this paper are representative of the methods now in use.

Conditioning the Well

Various preliminary operations for improving the results from plug-back operations have been evolved. In one method, a nitroglycerin shot is discharged at the upper portion of the formation to be plugged off, the purpose being to make a wide place in the hole in order to give the cement a more secure anchor against thrust pressure of the water against the bottom of the cement plug after the well is again put on production. Another is intended to attain a similar result by under-reaming a wide place in the hole by means of a rotary wall scraper. In one well in which this device was used there was a water sand at the bottom of the well immediately below the cap rock above which the oil sand occurred. Before the plugging back operation, the water sand was underreamed in an attempt to get a square shoulder on the underside of the cap rock, in order to prevent the water from breaking in over the top of the cement plug after the well should be put on production, and also to get a more secure anchor for the cement plug against the thrust pressure of the water against it.

As an aid in calculating the amount of cement required to fill a given amount of hole to be plugged back, a device has been developed for measuring and recording the irregularities and cavities in open holes, called an "open-hole recording caliper." It consists of a steel shell, 5 in. in diameter, which encloses a recording mechanism that receives impressions from four movable arms that make sliding contact with the wall of the hole. The arms operate a ratchet, which raises and lowers a recording stylus against a chart. Each arm registers its own radius. The device is run into a well on a steel measuring line. While the device is being lowered, the arms are folded inside the shell; they are

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tripped into open position when the device reaches bottom and the device is then raised slowly, allowing the arms to register.

Whether or not such special devices or methods are used, it is obviously essential that before a plug-back operation is started the bottom of the hole should be cleaned as thoroughly as possible, so that the cement slurry will have a good bond with the grains and pores of the formation to be plugged off.

"Balanced" Method of Plugging Back

The "balanced" method of plugging back is sometimes called "equalized" method, "equalized-column" method or "siphon" method. A tubing or drill pipe is run to the bottom of the well and then raised about one foot off bottom. Circulation is then established and maintained until the circulating fluid is equalized. A calculated amount of cement is then pumped into the tubing, followed by circulating fluid. This method depends upon the excess weight of the cement slurry over that of the circulating fluid causing the cement to equalize on the outside and inside of the tubing or drill pipe at the bottom of the well. It is essential that the circulating fluid pumped into the tubing after the cement slurry shall be the same kind and weight per gallon as that in the well on the outside of the tubing. In order to prevent any vacuum from affecting the equalization of the cement slurry, the upper end of the drill pipe and the upper end of the casing are both opened to atmospheric pressure.

After the cement has equalized inside and outside of the lower end of the tubing, the tubing is raised to a point just above the intended top level of the plug-back and the excess cement is circulated out of the well, either by circulating down through the tubing and up through the space between the tubing and the casing or by reverse circulation down through the casing and up through the tubing or drill pipe. Some operators prefer to use regular circulation down through the tubing when the lower end of the tubing is in open hole in which there are cavey formations and it is feared that if reverse circulation were used the fluid passing down through the casing and the open hole might cause a greater tendency for the formations to cave. However, reverse circulation removes the excess cement from the well in considerably less time than regular circulation, which is important in deep wells. The tubing is then raised to a safe level or withdrawn from the well and the cement is allowed to set before operations are resumed.

Displacement Method

This method is similar to the balanced method except that a measured amount of fluid is pumped into the tubing or drill pipe immediately after the cement slurry and the tubing or drill stem need not be opened to atmospheric pressure at the surface.

The simplest form of carrying out a displacement job, after the tubing is run to bottom, raised a foot off bottom, the mud equalized and the cement slurry pumped into the top of the tubing, is to pump in sufficient circulating fluid to fill all of the tubing or drill pipe except the lower portion, which is temporarily left filled with cement. The amount of cement left in the bottom of the tubing depends upon the amount of hole to be plugged back, sufficient cement being left in the bottom of the tubing to make sure that there is no contamination of the cement when the tubing is raised. If no cement were left in the bottom of the tubing, there would be contamination of the cement slurry by the circulating fluid when the tubing is raised.

The tubing is then raised to a short distance above the intended top level of the plug-back and the excess cement is washed out of the well by regular or reverse circulation. The cement is then allowed to set before operations are resumed.

That form of displacement method has been widely used with considerable success, yet there have been recent developments intended as improvements, included in the following step by step description:

1. Run the tubing or drill pipe to bottom.
2. Raise the tubing about one foot off bottom.
3. Circulate to equalize the mud.
4. Mix and pump into the tubing an amount of cement calculated to plug back a desired amount of hole, plus at least 25 sacks donated to the hole as scavenger. This excess cement scours the face of the formation ahead of the main body of cement. Although the scavenger becomes contaminated, it is washed back out of the well, as described later in step No. 8.
5. Pump in a measured amount of water to fill 500 ft. of tubing. Coloring matter may be added to the water in order to facilitate identification later in step No. 8.
6. Pump in a measured amount of mud to fill all but the bottom 700 ft. of tubing if less than 200 ft. of hole is to be plugged. This will leave 200 ft. of cement and 500 ft. of water in the lower end of the tubing when the pump is stopped. If more than 200 ft. is to be plugged, leave more cement in the bottom of the tubing.
7. Raise the tubing to approximately 2 ft. above the desired level for the top of the cement plug and start reverse circulation.
8. Watch the returns at the surface and be sure that when the water returns it is measured to see whether or not all of the 500-ft. slug has returned. Then watch for the return of the 25 sacks of cement donated to the hole as scavenger, which should follow the water to the surface. If all of the 25 sacks come back to the surface after the colored water, the job has been carried out as planned. If less than 25 sacks returns, the hole took more cement than was calculated. If no cement and no

colored water return to the surface, it is obvious that considerably more cement should have been used. (The colored water and excess cement that may be returned to the surface can be bypassed away from the mud pit to keep them from mixing with the regular circulating fluid.)

9. If the colored water and excess cement are recovered in sufficient amount, the tubing either can be raised several hundred feet and left hanging, later to be lowered to check up on the top level of the plug-back after the cement is set, or it can be pulled from the well.

10. If step No. 8 shows that an insufficient amount of cement has been used to reach the desired level and another plug-back job will be necessary, the tubing can be raised several hundred feet and allowed to hang for several hours until the cement sets sufficiently so that the second job can be done on top of the first job. This will eliminate the necessity of an expensive shutdown for the usual period, most operators preferring 72 hours.

The displacement method has some advantages not inherent in other methods in that it provides an immediate check on whether or not the calculated amount of cement was sufficient. If the amount used was not sufficient, preparations can be started immediately to do a second job in a few hours, when the cement has set sufficiently.

Plug Methods

Several methods have involved the use of cementing plugs made of wood or other material placed in the tubing before or after the cement slurry, or both before and after. While the displacement method has been more generally used than the more complicated plug methods, some operators have felt that special conditions would make the use of a plug method more desirable.

One method of using plugs is to run the tubing to the bottom of the well and then raise it until the bottom of the tubing is a few inches from the bottom of the well. A wooden cementing plug about 2 ft. long is then placed in the top of the tubing. The required amount of cement slurry is pumped into the tubing, then another wooden cementing plug about 3 ft. long, equipped with a leather cup on the upper end, is placed in the tubing. Cement slurry is pumped into the tubing on top of the second cementing plug, the amount being calculated to fill the lower end of the tubing up to a point above the intended top level of the plug-back. This column, consisting alternately of wooden cementing plugs and cement, is pumped down through the tubing until the first cement plug strikes the bottom of the well, shutting down the pump at the surface. The tubing is then raised 2 ft. to allow the first cementing plug to pass out of the tubing. The tubing is lowered again and cement is pumped around its lower end until the second cementing plug strikes the bottom of the well, shutting down the pump. The tubing is then raised

to a point about 2 ft. above the intended level of the plug-back and reverse circulation is established to wash out the excess cement.

Another type of plug-back job using a cementing plug was described in a paper by R. E. Watson[1], which involves the use of a special plug consisting of two swab cups on a mandrel and a seating shoe. An assembly consisting of a perforated bull plug, a collar with a valve seat for the special cementing plug, and a working barrel is placed on the bottom of the tubing. The tubing is run to bottom and the well is washed through the perforated bull plug. The required amount of cement slurry is pumped into the tubing, followed by the special cementing plug. Circulating fluid is then pumped into the tubing until the cementing plug reaches the assembly on the bottom of the tubing, at which time the seating shoe of the plug seats in the valve in the collar, shutting down the pump at the surface and indicating that all the cement slurry is outside of the tubing. The tubing is then raised the required distance and circulating fluid is pumped into the casing, reversing the circulation and forcing the special cementing plug and excess cement up through the tubing to the surface. To expedite the recovery of the special cementing plug, a chamber is previously installed on top of the tubing. This chamber consists of a tubing nipple long enough to hold the cementing plug, with a tee and a side outlet at the bottom end of the nipple and a gate valve below the tee.

There are several other adaptations of the plug method, but they have not been used for some time.

Squeeze Jobs

The word "squeeze," when applied to cementing jobs, means that the cement is forced, or "squeezed," into a formation or through perforations or leaks in the casing. When using this "squeeze" principle in plugging back operations the tubing is run to the bottom of the well and raised a few inches off bottom and the bradenhead is connected up between the casing and the tubing at the surface. With the bradenhead open, circulation is established and maintained until the circulating fluid is equalized, after which the required amount of cement slurry is pumped into the top of the tubing. If the amount of cement slurry pumped into the tubing is sufficient to fill all of the tubing, the bradenhead is closed when the lower end of the cement column reaches the bottom of the well. If the amount of cement slurry is not sufficient to fill the tubing, circulating fluid is pumped into the tubing after the cement slurry. In either case, the bradenhead is closed as soon as the bottom of the cement column reaches the bottom of the well. With the bradenhead closed, and by pumping circulating fluid into the top of the tubing,

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[1] R. E. Watson: Cementing Methods for Excluding Water from Producing Wells. Amer. Petr. Inst., Tulsa, Okla., meeting, May 16, 1935.

the only place for the cement slurry to go is out into the voids or erosions in a permeable formation. If the formation takes the cement slurry, pumping is continued either until a pressure limit has been reached or until so much of the cement slurry has been pumped out of the tubing that only a sufficient amount is left in the tubing to prevent contamination when the latter is raised. The pressure is then released at the bradenhead and the tubing is raised to a point just above the intended top level of the plug-back, and reverse circulation is established to wash the excess cement out of the well. The tubing is then raised several hundred feet, the bradenhead is closed and pressure applied. The well is shut in under pressure until the cement has had time to set sufficiently to resume operations.

In another adaptation of the "squeeze" job the mechanical hook-up is similar to that just described except that a stuffing-box arrangement is installed on top of the casing at the surface through which a joint of tubing or drill pipe about 30 ft. long can be raised or lowered. The tubing is run to bottom and raised about a foot off bottom. Water is then pumped into the tubing in sufficient amount to fill all the tubing and the space outside of it at the bottom of the well up to a point just above the intended top level of the plug-back. With only a 30-ft. stroke through the stuffing box at the surface the plug-back is limited to less than 30 ft. from the bottom of the well. If it is necessary to plug back more hole, it can either be done in stages or several joints of flush joint tubing or drill pipe can be used to work through the stuffing box. After the water has been placed, the bradenhead below the stuffing box at the surface is shut in. Water is then pumped into the top of the tubing and the only place for the water to go is out into some open formation at the bottom of the well. Inasmuch as the reason for doing a plug-back job of this type is usually for the purpose of shutting off water coming from a formation or part of a formation in the bottom of the well, the water pumped in under this method will usually first go out into the water-bearing portion of the formation. By watching the amount of pressure required to force water out into the formation, the amount of cement to be used can be approximated. The cement slurry is then pumped into the top of the tubing; if the pump pressure is somewhat high at that time, slowing up the pumping of the cement down the tubing, the bradenhead may be opened until the bottom of the cement slurry reaches the lower end of the tubing. The bradenhead is then closed and the only place for the cement slurry to go is to follow the water into the formation. By again watching the increasing pump pressure required to force the cement out into the formation, the point at which the cement has been "squeezed" sufficiently into the formation can be gaged and the pump can be stopped, to prevent the forcing of cement into the oil-bearing formation. The tubing is then raised through the stuffing box, still

under pressure, to a point about a foot above the intended top level of the plug-back and reverse circulation is established down through the casing, up through the tubing and out through a valve at the top of the tubing, the valve being adjusted to maintain a suitable back-pressure while the circulating fluid and excess cement are circulated out of the tubing. When the excess cement is washed out of the tubing the valve is closed and an equal pump pressure, up to the amount required to "squeeze" the cement into the formation, is applied on both tubing and casing, if necessary. The cement is then allowed to set before operations are resumed.

Plugging Back in "Thirsty" Formations

There are formations that are sufficiently permeable to take the cement slurry without any pressure other than the hydrostatic pressure of the cement slurry and the circulating fluid. As an example, in one recent plug-back job of this type, 300 sacks of cement were required to plug back 30 ft. of a hole that had been cut by a 6⅛-in. bit. It is true that sometimes large wallows are encountered in open hole in unconsolidated formations, caused either by a hydraulicking effect of the circulating fluid through the drilling bit or by erosion while the well is being produced, but in this case the excess cement required is attributed to a highly permeable formation.

When plugging back in "thirsty" formations, one of three general methods is now being used. One method is to use regular cement slurry and make successive plug-back jobs, by a displacement or in any suitable way, using a small amount of slurry in each job and allowing an interval of several hours between jobs. Another method is to lighten the weight of the cement slurry by using a cement-bentonite mixture. The latest method, however, is to use a self-sealing cement, which contains a fibrous sealing material premixed with the cement in dry state at the cement plant; the idea being that when the cement begins to flow out into the formation the fibrous materials begin to wad up and build a seal against further entry of the cement slurry.

Plugging Back in Screens or Perforated Liners

When a screen or perforated liner is in a well to be plugged back, and is not easily removed, cement can be placed in the lower part of the liner back to the desired level by the displacement method. This procedure is not only the least expensive by far, but, if properly done, can be made as effective as plug-backs made in the water portion of a continuous sand body, especially when the flowing conditions in the well, when on production, are controlled so that there is a small differential of flowing pressure adjacent to the cement plug.

When the water sand at the bottom of a well is separated from the oil sand by impermeable formations, and the screen or liner is not easily removed, and it is desired to separate the sands with cement, cement can be placed outside of the liner through perforations by an adaptation of the "squeeze" method. Cement is left inside of the liner to the desired level.

Summary

In order to get the most successful results from plug-back operations, it is necessary first to condition the well for the job, select the method that appears most suitable for the conditions in the well, add a quantity of cement slurry for donation to the hole as a scavenger, circulate the excess cement out of the well, and determine the location of the actual top level of the plug-back before resuming operations. Aside from the purpose of shutting off bottom-hole water, some of these methods have been very successful in plugging back for side-tracking and other purposes.

Chapter III. Petroleum Economics

The Role of Drilling in the Functioning of Proration

By Joseph E. Pogue,* Member A.I.M.E.

(New York Meeting, February, 1936)

For the purposes of this analysis it is assumed that the petroleum industry has undergone a basic economic change whereby the degree of competition present in its operation is reduced by the collective control of production brought about by state-directed proration. Formerly freely competitive in all its parts, the industry is now fully competitive only in its marketing, its manufacturing and transportation, its search for new oil supplies, its drilling operations (with some qualifications), and its capital movements. The practical problem before the industry in its new status is the maintenance of equilibrium, with planned control of crude-oil production (proration) substituted for competition and price as the regulatory mechanism at one point in the supply-demand system. It is further assumed that proration has become so firmly established in the legal and operating framework of the business that it may be looked upon as an institution. The purpose of this paper is to call attention to the effect of unregulated drilling upon the orderly functioning of proration.

Economic Structure of Petroleum Industry

The economic structure of the petroleum industry, under the current form of proration, may be visualized, in simplified form, as shown in Fig. 1. This diagram is designed to indicate the existing mechanism whereby supply and demand are equated. Demand is created largely by conditions external to the oil business, whereas supply is conditioned by a series of stages incidental to the discovery, development and production of a resource. The time elements involved in changes in demand and supply are of an entirely different order, the demand factor being much more flexible and "quicker" than the supply factors. It should be observed, also, that the position of price, formerly between "demand" and "supply," has been moved to a sidewise location where it still affects demand but influences current supply only through its bearing upon proration, drilling and search. Proration has been substituted for price as a throttle at the well head, *but at this point only*. The mechanism now works in this fashion: a declining price stimulates demand and the

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effective operation of proration; retards developmental and wildcat drilling. A rising price does the reverse. The industry apparently entertains the idea that rising prices strengthen the control, and vice versa, but this view is probably valid only in a zone of mild price changes and over a short-run period.

With further reference to Fig. 1, the several elements entering into the economic structure may be examined in order. Demand is determined by the price at which petroleum products are offered, the utility of these

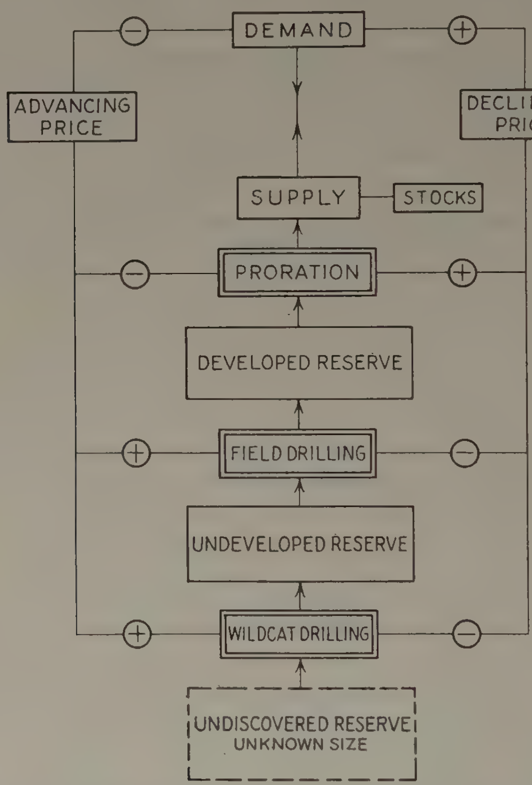

Fig. 1.—Diagrammatic sketch of economic structure of petroleum industry under proration, showing effect of price upon various parts of system.

products, the national fund of purchasing power, and the prices and availability of substitutes. The petroleum industry can influence demand only through price and quality; it cannot regulate demand. Demand, therefore, is determined by competitive conditions and can be affected by proration only *adversely*.

Supply is now specified by quotas of allowable production, set on the basis of providing what the market requires, with no formal reference to price. Practically, demand is estimated on the basis of the prevailing price. The normal function of price in equating supply in terms of

demand is abrogated by proration. With respect to current supply, taken alone, price in theory can be at any level whatsoever. In practice, however, actual price must be limited by demand and the factors lying back of current supply, each category being sensitive to price and quite responsive to it. Price is also restricted by the strength of proration, rising prices being stimulative to evasion. The units and agencies involved in proration, however, are likely to be more interested in high prices than in low prices. The temptation is constantly present to utilize proration for price-raising purposes, but there are many countervailing economic forces.

Back of current supply are four reservoirs from which production is fed and upon which, in the long run, production is dependent. These are: the crude-oil inventory, the developed reserve, the undeveloped reserve and the undiscovered reserve. The first is an isolated unit; the last three are in sequence. The above-ground inventory includes a necessary working stock and a variable surplus. This inventory is now approximately 300 million barrels, of which roughly 200 million barrels are regarded by some as a working stock, leaving a surplus of 100 million barrels. The above-ground inventory acts as a governor to adjust sudden changes in supply and demand; it is occasionally called into action for speculative purposes. It is subject to price control, normally tending to expand at low prices and to contract at high prices.

The developed, or drilled-up, reserve is the primary factor underlying current supply. Proration evolved when this factor became excessive, in order to throttle back the surplus "potential." The rapid expansion of the potential in the late twenties led to the breakdown of the price structure in 1930–1931. An excessive rise in the potential would doubtless again undermine proration and wreck the price structure. In practice, the potential must be held within such bounds as not to tax the strength of the production control. The excess potential represents frozen capital and a rise in unproductive capital represents a strain leading to trouble if the critical limits of the system are transgressed.

Reserves

The developed reserve is created from the undeveloped reserve through the medium of drilling. The available drilling statistics are not separated into their two functional components: field wells and wildcat wells. However, as wells drilled in "proven" locations are seldom dry, while wildcat wells are for the most part nonproductive, the number of oil wells completed constitutes a good index of the rate of drilling of field wells, while the number of dry holes completed forms an index of the rate of wildcatting[1]. There is a high degree of correlation between the

[1] For the suggestion that dry holes constitute an index of wildcatting effort, the writer is indebted to Mr. E. L. DeGolyer.

price of crude oil and the number of oil wells drilled, so that it is evident that development drilling is quite responsive to price and fluctuates with variations in price. See Fig. 2. Price is accordingly an effective regulator of drilling. Should proration be employed to valorize crude oil, the stimulating effect of price upon drilling, unless means are found for its inhibition, would normally lead to the development of disequilibrium and an ultimate breakdown of the price structure.

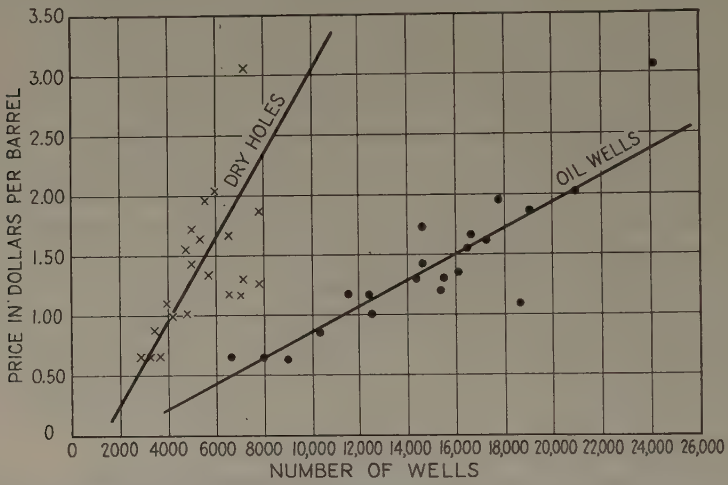

Fig. 2.—Correlation between weighted average price of crude oil and (*a*) number of dry holes drilled and (*b*) number of oil wells drilled—the indexes, respectively of wildcatting and development effort. Data are for years 1915–1935.

Back of the undeveloped reserve and feeding into it through the agency of wildcat drilling, is the undiscovered reserve, which is of indeterminate magnitude. The accretions to the undeveloped reserve are determined by the discovery rate, which in turn is conditioned by the number of wildcat wells drilled, by the technique entering into this exploratory effort, and probably also, in respect to short periods of time, by the element of chance. In the long run, however, chance is eliminated by accumulated effort. There is some degree of correlation between the price of crude oil and the number of dry holes drilled, so that search is stimulated or retarded by price (Fig. 2); but the control is imperfect. Search is also motivated by the condition of the capital market as reflected in interest rates and tends to be stimulated by successful discovery. For example, cheap money tends to increase wildcatting, and vice versa; while the opening of a new petroliferous province generates an expansion of drilling effort. Also the discovery response to the wildcatting effort is very erratic, being influenced by current technique and by rhythms of success or failure of the nature of "runs of luck." Furthermore, the mere fact that the undiscovered reserve is, and must remain, indeter-

minate leads to a persistent effort to build up corporate reserves of crude oil, based upon the innate apprehension that the ultimate supply is limited. For these reasons price is a somewhat ineffective regulator of discovery, at least when viewed over short periods. Nor would it appear practical to "plan" discovery, since the factors going to create discovery are so variable in their cause-effect relationships. The rate of discovery, therefore, is the most elusive and obdurate factor in the oil economy, and yet, in the last analysis, it is the most important element in the problem of maintaining equilibrium. An excessive discovery, if long continued, will inevitably bring about lower prices, even in the presence of proration, just as a deficient discovery rate is bound, in the long run, to generate price advances.

Ultimately the discovery rate will decline because of the exhaustion of prospects through the process of elimination, but there is no positive evidence that this time is at hand. The discovery rate up to the present has been competent to maintain an adequate underground working stock; in fact, in late years, the reserve, or at least its degree of development, has tended to become excessive as witnessed by the development of proration to hold it back from the market. The economics of the oil business is pivotally dependent upon the future course of the discovery curve; if it fails from a natural exhaustion of the resource, then prices will, and *should*, rise to stimulate the development of more efficient utilization and of substitutes. If, on the other hand, the resource is adequate to support discovery for a considerable period, the existence of a profitable price and the constant progression of technology will create a momentum that will upset the balance and call for a downward revision of prices, unless a barrier is interposed to retard the development of the reserves resulting from a high discovery rate. Proration at the well head will not be competent to handle the situation postulated.

What can be the nature of this supplementary barrier? There are three available expedients conducive to retarded drilling, aside from lowered prices: (1) unit operation, (2) employment of acreage factors in proration formulas and (3) controlled well spacing. Unit operation permits the owner or joint owners of an oil pool to retard and reduce drilling where there is an economic advantage in following such procedure —a choice denied the operators in the freely competitive pool because of the operation of the rule of capture. Under proration, the type of formula employed by the regulatory commissions in calculating lease allowables has an important bearing upon the rate and volume of drilling; where the principle of ratios of potentials to acreage is introduced a rational drilling program is furthered, whereas the absence of the acreage feature puts a premium upon uneconomic drilling. In prorated pools, also, controlled well spacing is available as an instrumentality for lessening the incidence of drilling. In most cases the state regulatory bodies

have authority to prescribe the lease formula and the well spacing in new fields, but their action in many cases seems to reflect expediency or a short-term viewpoint.

Summary

The thesis has been advanced that proration, even though effective in balancing current supply and demand, tends to create unbalance by stimulating discovery and subsequent overdrilling. This tendency is brought about by the price structure that the control inclines to establish. The only effective natural opposing factor is a deficit discovery, but a temporary condition of this kind is apt to become the basis of a rationalization process and persist after the condition has changed. Proration, therefore, except under conditions of subnormal discovery, cannot be depended upon as a competent instrumentality for maintaining equilibrium, unless it does one of two things: (1) produces a price that will keep discovery and development drilling in equilibrium with demand, which probably would have to be a low-profit price; or (2) develops an effective restraint on drilling which will prevent the discovered, but undeveloped, reserve from absorbing capital too rapidly and thus becoming converted into an excess potential.

A program for the effective support of proration should, therefore, include the following provisions:

1. Furtherance by the petroleum industry of a consistent policy of relatively low oil prices so long as potentials are large and the discovery rate shows any tendency to exceed the production rate; so long, too, as a maximum demand is a desideratum in maintaining balance.

2. Promotion by the petroleum industry of retarded field drilling through wider well spacing and unit operation.

3. Advocacy by state regulatory bodies of formulas for lease allowables that will normalize, and not overstimulate, drilling. The acreage factor will accomplish this result.

4. Support by state regulatory bodies of prescribed programs of wide well spacing.

DISCUSSION

W. E. Pratt,* Houston, Tex. (written discussion).—I had the opportunity of reading Dr. Pogue's paper before publication and of telling the author how well I thought he had done the job. Therefore, let me repeat here only the critical comment I sent to Dr. Pogue.

Dr. Pogue is a realist. It is perfectly apparent to him, as it is to the rest of us, that proration has never yet functioned perfectly. In view of the failure of proration to date he suggests supplementary barriers to the flow of developed reserves into supply. The suggested barriers are: (1) unit operation, (2) employment of acreage factors in

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* Vice President, Humble Oil & Refining Co.

proration formulas, and (3) controlled well spacing. My feeling is that the last two suggestions are fundamental parts of any system of proration worthy of the name. That is to say, there can be no reasonable hope for the success of a system of proration that does not take acreage into consideration in its allocation formulas either directly or through the control of well spacing and well allowables. The point is that these devices are not something outside of proration, as I conceive it, but are an integral part of proration itself. An attempt has been made to include them in the rules for nearly every field to which proration has been applied from the beginning of the proration effort, and proration must include them before it can be successfully applied; but they are a part of proration as it should be, not something outside of proration.

Dr. Pogue speaks more than once of the effect of proration on price. He states, for example, that proration cannot be depended upon to maintain equilibrium unless, among other things, it "produces a price." Again I say Dr. Pogue is a realist. He knows as we all do that proration cannot be applied practically without an effect on prices. Yet, in theory, proration has no concern with prices, and, in my judgment, proration becomes indefensible the moment it is utilized for the purpose of controlling prices. If we hope through proration to jack up prices, we are doomed to disappointment, just as the promoters of control in the rubber industry were disappointed. Prices ought to be beyond the scope and effect of proration.

Proration by the state authorities has no basis in law except conservation; that is, the prevention of physical waste of a natural resource. Nothing can be done legally through proration except it be effective in preventing physical waste. Even limitation of production to market demand has no other justification than its salutary effect in the prevention of physical waste.

The Future of State and Federal Oil Regulation

By Northcutt Ely*

(New York Meeting, February, 1936)

A year ago the petroleum code was in effect, and Congress had before it bills with powerful backing designed to extend and put on a permanent basis the Federal authority impliedly recognized in the petroleum code. Those men in the industry who were convinced of the unconstitutionality of Federal regulation, who believed in conservation, and who were seeking accomplishment of a conservation compact among the oil-producing states, were at that time encountering difficulties in bringing about such an agreement. Since then there has been a shift in the center of gravity. Today, by virtue of the Supreme Court's Schechter case decision, the petroleum code is not in existence, the industry is not operating under an oil administrator, and the Federal-control bills are not on Congress' calendar. In view of what the Supreme Court has said in the Schechter case and the Hoosac Mills case about the local character of mining and manufacturing, the problem today is not whether the Federal Government or the State Governments ought to regulate oil production, but how effective we can make the devices that are available to us under the constitution for the conservation of the nation's oil resources. The interstate oil conservation compact ratified during the past year by Texas, Oklahoma, Kansas, New Mexico, Colorado and Illinois, approved by Congress, but not yet in effect in California, is the mechanism now at work.

Interstate Oil Conservation Compact

What is this interstate compact? The basic theory is simple and logical. It has four elements to it. The first point is that in order to effect the maximum recovery of our oil and gas reserves it is necessary for some governmental authority to regulate the way in which those resources are taken out of the ground, so that the reservoir energy is efficiently used, and used equitably by the various owners of the pool. Second, that the state, as distinguished from the national government, possesses the police power necessary to protect the public interest and to protect the correlative rights of the common owners of the oil pool. Third, that the state governments ought to cooperate with each other through an interstate advisory commission so that orderly production in one state is

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not penalized by losing its outlets to uncontrolled flush production from another state. And, fourth, that the Federal Government ought to supplement the state's activities by performing three functions: first, preventing the interstate movement of hot oil (that is, oil produced in violation of state regulations); second, controlling imports; and, third, making findings of fact and forecasts as to supply and demand for the assistance of the Interstate Compact Commission and of the state governments. That, in essence, is the kind of a compact agreed upon at Dallas by nine of the oil states in February of 1935, ratified by six of them, and approved by Congress in August of 1935. The compact pledges the individual states to carry out half a dozen major conservation principles, all looking toward promoting the maximum ultimate recovery of oil and gas. The Interstate Compact Commission is a coordinating body. It has been working for several months in an unostentatious but effective way. The Bureau of Mines has periodically made its forecasts; the Interstate Compact Commission has received them, discussed them, and passed them on to its state regulatory bodies; and they have followed the Federal recommendations voluntarily but fairly closely. California is not a member of the Compact, and the compact system cannot become completely effective until she is a member and has an effective local conservation law.

There have been important changes in the conservation laws of Kansas, Oklahoma, Texas and New Mexico, four of the compacting states. Those amendments were made law during the germination of the Compact proposal, but before actual ratification of the Compact. The Compact Commission has committees at work studying the possibility of uniform state conservation laws. That phase of its work is part of the movement toward sound conservation laws that has been urged by every authoritative body that has studied the problem, including the Stabilization Committee of the American Institute of Mining and Metallurgical Engineers. We are all beginning to understand, as a result of the educational work of the petroleum engineers, the functions of reservoir energy and the necessity for its wise use, the bad effects of the law of capture, and the necessity of finding some alternative legal system while there is still time for it to be effective. The Compact, having become a statute in the states ratifying it, sets up those objectives in the municipal law of the state as well as setting up an interstate commission to handle the state's external problems with other compacting states.

The Compact itself is necessarily a compromise. It is an agreement entered into voluntarily by six states with widely different political backgrounds and conceptions of the state's authority, and subject to different interpretations by their own courts of that authority.

It expires by its own terms in September of 1937, and if renewed, a new compact must be negotiated then. It is not as complete an instru-

ment as that which the Federal Oil Conservation Board proposed in 1932, but it is the best engine we have available at the moment for use in the cause of oil conservation.

It ought to be apparent to everyone that this kind of a voluntary arrangement among half a dozen or more sovereign states, with nothing compulsory about it, is going to do just as much or just as little for the cause of conservation as the enlightened public opinion in those states and in the petroleum industry as a whole demands.

Future of the Compact

Three things can happen to the Interstate Compact.

First, now that the fear of Federal control has subsided, the industry may lose interest in the Compact and let it fall to pieces. If that happens, it will be a tragedy for the industry itself, a tragedy for the principles of local self-government, and a tragedy to the consumers who must depend on these oil-producing states for a long-continued supply of oil at reasonable prices. It is not going to happen if the governors and other state officers who have earnestly tried to work this problem out are properly supported by the industry.

Second, the compact system can take strong root, receive the vigorous support of the industry and of enlightened conservationists, and do many of the things for protection of our irreplaceable reserves that the advocates of Federal control have insisted were their own objectives, and yet accomplish those purposes in a constitutional way without infringing local powers of self-government of our people. If the Compact is to succeed in that way, the states have got to be kept actively interested in it, the industry has got to support it, adequate appropriations must be made for the Interstate Compact Commission, and the state regulatory bodies must be brought fully into that Commission's operations.

Third, the Compact may be overshadowed by an unexpected resurgence of the demand for Federal regulation. The public has been indifferent to conservation of oil and gas because the price of gasoline has never reached a resistance level. But if the Compact fails, if our petroleum reserves are selfishly used, and if the pocket nerve of the consuming public is suddenly pinched, the industry may encounter demands for regulation of a character that will make preceding attempts seem mild.

The movement for greater Federal control of the oil business has not run its course. A variety of activities has been suggested. Those who think that the Federal Government's power to regulate oil production under the war powers cannot be effectively exercised in peacetime may overlook the possibility that future neutrality legislation might form the basis for regulations carrying the Federal Government's supervision of the oil business deeper than it has yet gone. There is going to be stronger agitation for Federal regulation of pipe lines, particularly gas lines.

Gasoline taxes, Federal and state, are not coordinated. When gasoline leaves the refinery, the petroleum industry has received as its reward for finding the oil, bringing it to the surface, transporting it to the refinery and processing it, about the same amount of money per gallon as the state and Federal governments thereafter take in gasoline taxes. It has been suggested that if there is going to be an involuntary partnership of this sort, the three partners ought to protect each other's interests; that the Federal Government ought to be authorized to furnish data to all the states on refinery shipments, and it ought to be authorized to collect at the refinery state gasoline taxes for such states as want to have that service performed.

The Federal Government has a legitimate function in studying the demand for petroleum and its products and in studying the sources from which that demand ought to be supplied. There is a feeling that the Bureau of Mines has functioned well and its work ought to be strengthened. In the control of imports and exports, it is conceded that the Federal Government is capable of functioning where the states and the industry are not. The method of adjusting our imports and protecting American investments in foreign fields is not yet entirely satisfactory, and little has been attempted toward governmental agreements for protection of our export trade. There is wide recognition of the necessity for Federal control of interstate shipments of hot oil, on a permanent basis. Whether one believes that Federal activities ought to expand along any of these many lines or not, it is a mistake to think that the end of the Federal petroleum code was the end of Federal interest in the oil business or in the oil reserves on which our national routine is dependent.

Today the oil industry has more intelligent information about our oil reserves and how to make them serve our people than it ever had before. There is a clearer idea prevailing of the relative powers and functions of the state and Federal governments than there has been previously. There is available in the Interstate Oil Compact the beginnings of a system in which the Federal Government, the state governments and the industry can cooperate in protecting the public as well as private interest in our oil and gas resources. Let us hope that this program will develop into the effective mechanism that it can become.

This Compact is one step in a process of evolution. A dozen years ago we came out of a period of supposed scarcity into one of very high immediate potential production, and apparently we are going to face, sooner or later, a period within which new discoveries are going to be welcomed rather than dreaded. When diminishing reserves plus increasing state taxation make the motorist begin to realize his stake in the oil business, there is going to be intense public interest in the industry and in ways to make it furnish more gasoline and more taxes. What must ultimately evolve is a regulatory system which will work both ways; that is, retard

waste of reservoir energy through excessive flush production in our day, and tend to keep future production up to required levels when the present flush fields fade out.

The industry itself in its relations with the Federal and state governments has grown accustomed to alternating periods of extreme anxiety and of contented indifference. But nearly every step toward governmental control of the industry has originated within the industry itself; state proration, the Federal petroleum code, the Federal control of imports, the Federal control of hot oil, are some examples.

The petroleum industry is one of the largest going concerns on the face of this earth. So also in his time, many ages ago, was the dinosaur. A characteristic of the prehistoric monster was the simplicity of his nervous system. It is said that these animals probably never knew the meaning of fear, except in the form of a paroxysm of terror; that they went contentedly about their business, whether, depending on the nature of the beast, it was the business of chewing tree tops or the business of digesting their smaller neighbors; that they lacked all capacity to worry about the past or the future, but were capable of breaking into violent activity to escape impending danger. Ultimately there were no more dinosaurs. The nervous system that was capable of convulsing huge pieces of machinery into violent activity, but was incapable of remembering the past or planning for the future, did not survive. If we take only spasmodic interest in the wise use of our huge but diminishing oil resources it is likely that selfish interests, political and otherwise, will eventually capture the oil industry just as the ants ate the dinosaurs.

World Consumption of Petroleum Products

By V. R. Garfias* and R. V. Whetsel*

(New York Meeting, February, 1936)

It is estimated that world consumption of petroleum, its products and related fuels during 1935 will reach an all-time peak of 1,592,000,000 bbl.—about 5.4 per cent higher than in 1934. Demand increased within the United States approximately 6.1 per cent during 1935 and in foreign countries about 4.1 per cent.

The figures in Table 1 indicate that during the past five years world's production of crude petroleum and related fuels exceeded demand

Table 1.—*Production and Consumption of Oil*
Thousands of Barrels

	World Production	World Consumption	Excess Production over Consumption
1931	1,432,142	1,417,374	14,768
1932	1,362,039	1,348,407	13,632
1933	1,467,128	1,406,923	60,205
1934	1,562,834	1,510,360	52,474
1935[a]	1,690,420	1,592,585	97,835
	7,514,563	7,275,649	238,914

[a] Estimated from statistics available in December.

every year and that the aggregate difference is approximately 239,000,000 bbl. The supply in the United States exceeded consumption by some 134,000,000 bbl. over the same five-year period, while outside the United States the excess over demand is shown to be 105,000,000 bbl. Table 2 combines the excess production in the United States with its favorable balance of exports over imports, showing that the United States has reduced its storage over the five years by about 132,720,000 bbl., and indicates that, including its excess of imports from the United States, the rest of the world may have an unfavorable balance of some 371,000,000 bbl. over the five-year period. Such difference in foreign countries is largely due to increase in stocks, and partly at least remains in our imperfect knowledge of consumption statistics as an unfavorable balance. Table 3

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* Foreign Oil Department, Cities Service Co., New York, N. Y.

shows the world's consumption classified by countries according to the principal products for the past three years.

These tables also indicate that at the end of 1935 the position of the petroleum industry outside the United States has not improved despite increased consumption, and that in the United States withdrawals from storage have been made possible only by increased exports, which are

TABLE 2.—*Amount of Oil to Storage*
THOUSANDS OF BARRELS

Year	Excess Production over Consumption		Excess Imports over Exports	Excess Imports from U.S.A. over Exports to U.S.A.	Total to Storage	
	United States	World Outside U.S.A.	United States	World Outside U.S.A.	United States	World Outside U.S.A.
1931	5,815	20,583	38,788	38,788	44,603	59,371
1932	13,011	26,643	28,781	28,781	41,792	55,424
1933	67,427	7,222	60,254	60,254	7,173	53,032
1934	26,165	26,309	64,013	64.013	37,848	90,322
1935[a]	59,150	38,685	74,800	74,800	15,650	113,485
Total......	133,916	104,998	266,636	266,636	132,720	371,634

[a] Estimated from statistics available in December.

adding to stocks in foreign countries, thus creating an unfavorable situation abroad that sooner or later may be reflected in the United States. Despite a marked increase in consumption and exports withdrawals from storage within the United States during 1935 were over 50 per cent less than in 1934; hence it is evident that the time has not yet arrived when the American petroleum industry can in any way let up on its curtailment program.

TABLE 3.—*World Consumption of Petroleum Products and Related Fuels*

THOUSANDS OF BARRELS

	1933						1934		
	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Motor Fuel	Kerosene	Gas and Fuel Oil
United States	377,033	38,493	316,344	17,152	119,466	868,488	407,106	44,234	331,989
Russia	9,308	25,033	52,518	7,133	15,242	109,234	12,759	27,489	53,568
United Kingdom	33,070	5,475	21,645	2,880	2,897	65,967	34,254	6,515	26,511
France	21,268	1,522	12,594	2,019	1,156	38,559	21,400	1,810	13,510
Canada	15,016	1,608	13,520	757	1,912	32,813	16,210	1,712	14,341
Germany	12,334	841	7,468	2,001	1,893	24,547	15,205	910	8,646
Argentina	5,267	949	12,805	283	910	20,214	5,503	1,132	13,066
Japan	5,380	833	10,284	1,288	808	18,593	6,472	1,100	12,836
Mexico	1,765	583	11,091	121	2,175	15,735	1,916	604	11,287
Rumania	726	1,262	10,871	195	1,546	14,600	782	1,351	11,667
British India	2,085	5,899	3,382	877	920	13,163	2,265	6,114	3,573
Italy	3,844	1,343	6,600	581	1,204	13,572	4,003	1,410	7,000
Netherlands East Indies	1,610	2,275	4,610	544	1,310	10,339	1,533	2,330	4,770
Australia	5,724	1,201	2,631	336	338	10,280	6,480	1,047	2,840
Netherlands West Indies	160	21	8,194	22	1,830	10,227	172	23	11,486
China	744	4,460	2,276	264	93	7,837	945	2,855	3,728
Iran	673	1,285	3,259	660	1,410	7,287	704	1,315	3,411
The Netherlands	3,391	1,464	2,092	427	329	7,703	3,280	1,453	1,965
Venezuela	507	17	757	28	4,545	5,854	517	20	738
Brazil	2,005	629	2,945	165	32	5,776	2,250	724	3,010
Sweden	2,930	719	2,003	294	378	6,324	3,050	739	1,845
Spain	3,032	215	1,502	174	402	5,325	3,547	113	2,297
Belgium	2,589	304	978	242	107	4,220	2,759	260	1,237
Denmark	1,840	680	1,630	182	54	4,386	2,251	618	1,732
Egypt	179	2,061	1,506	165	131	4,282	552	2,059	1,988
Cuba	230	80	1,974	38	81	2,403	541	72	3,643
Union of South Africa	2,149	342	605	154	147	3,397	2,647	658	552
Norway	895	264	2,090	92	85	3,426	980	276	2,289
Philippine Islands	891	590	1,790	102	90	3,463	860	580	1,822
Czechoslovakia	1,911	553	812	214	140	3,630	1,958	502	779
Switzerland	1,661	186	1,014	137	15	3,013	1,857	195	1,155
Hawaiian Islands	909	129	1,624	44	59	2,765	920	130	1,810
New Zealand	1,590	130	816	72	71	2,679	1,847	115	1,185
Poland	789	943	401	308	378	2,819	809	1,000	364
Trinidad	122	63	2,030	31	236	2,482	120	70	2,282
British Malay	414	259	1,519	52	218	2,462	710	298	1,686
Chile	389	65	1,315	32	12	1,813	619	56	1,424
Uruguay	590	210	1,410	29	18	2,257	610	218	1,489
Panama Canal Zone	80	24	1,792	11	17	1,924	89	27	1,921
Iraq	185	182	832	39	210	1,448	322	205	1,310
Irish Free State	923	394	147	65	150	1,679	1,014	465	214
Austria	848	276	693	137	131	2,085	874	288	769
Algeria	1,138	377	244	107	86	1,952	1,201	394	301
Peru	428	461	509	32	188	1,618	431	452	552
Hungary	438	422	362	73	71	1,366	439	441	577
Greece	393	147	777	41	32	1,390	356	151	982
Porto Rico	449	65	806	22	23	1,365	460	67	871
Portugal	432	368	267	31	47	1,145	502	452	288
Finland	511	282	96	65	72	1,026	582	337	131
French Morocco	696	100	77	48	71	992	764	101	81
Others	4,903	4,575	15,339	786	1,396	26,999	6,626	5,248	16,696
Total	536,684	110,659	552,846	41,552	165,182	1,406,923	584,053	120,735	594,214

TABLE 3.—(*Continued*)

	1934 (*Continued*)			1935					
	Lubricants	Miscellaneous	Total	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total
United States	18,484	118,351	920,164	435,300	47,500	346,400	19,900	126,900	976,000
Russia	7,710	15,774	117,300	13,565	28,555	56,112	8,150	16,888	123,270
United Kingdom	2,882	2,008	72,170	37,454	6,015	25,894	2,692	2,121	74,176
France	2,160	1,675	40,555	22,200	1,890	14,210	2,110	2,000	42,610
Canada	808	1,621	34,692	16,650	1,750	14,700	830	1,690	35,620
Germany	2,550	1,920	29,231	15,810	1,010	8,850	2,660	2,010	30,340
Argentina	293	792	20,786	5,710	1,180	13,700	320	850	21,760
Japan	1,544	996	22,948	7,122	1,130	13,800	1,602	1,220	24,874
Mexico	147	2,380	16,334	2,100	610	11,400	160	2,580	16,850
Rumania	206	1,680	15,686	790	1,380	11,900	220	1,700	15,990
British India	923	990	13,865	2,300	6,200	3,700	950	1,080	14,230
Italy	582	1,379	14,374	4,563	1,502	7,600	615	1,660	15,940
Netherlands East Indies	526	1,400	10,559	1,600	2,390	4,900	540	1,480	10,910
Australia	330	402	11,099	6,600	1,090	2,990	400	500	11,580
Netherlands West Indies	29	2,140	13,850	180	25	11,800	30	2,400	14,435
China	270	102	7,900	1,034	2,666	3,010	281	111	7,102
Iran	590	1,487	7,507	710	1,380	3,600	610	1,510	7,810
The Netherlands	312	610	7,620	3,410	1,680	2,110	400	810	8,410
Venezuela	21	4,945	6,241	520	22	900	28	5,200	6,670
Brazil	163	38	6,185	2,400	750	3,200	170	50	6,570
Sweden	339	393	6,366	3,200	750	1,890	360	420	6,620
Spain	205	419	6,581	3,700	150	2,500	220	430	7,000
Belgium	401	112	4,769	2,662	248	1,202	397	114	4,623
Denmark	200	236	5,037	2,290	680	1,802	217	260	5,249
Egypt	167	127	4,893	560	2,100	2,150	190	140	5,140
Cuba	38	62	4,356	560	75	3,800	44	80	4,559
Union of South Africa	199	157	4,213	2,800	710	610	210	180	4,510
Norway	77	88	3,710	970	270	2,240	78	90	3,648
Philippine Islands	98	104	3,464	900	600	1,900	110	120	3,630
Czechoslovakia	211	146	3,596	2,050	550	810	240	180	3,830
Switzerland	145	21	3,373	1,892	200	1,140	147	25	3,404
Hawaiian Islands	49	62	2,971	940	130	1,760	50	65	2,945
New Zealand	69	83	3,299	1,900	120	1,240	75	100	3,435
Poland	401	359	2,933	815	1,040	370	410	370	3,005
Trinidad	30	280	2,782	124	73	2,300	32	300	2,829
British Malay	48	198	2,940	730	310	1,700	50	200	2,990
Chile	37	15	2,151	680	60	1,500	40	25	2,305
Uruguay	32	21	2,370	620	220	1,510	35	25	2,410
Panama Canal Zone	12	22	2,072	95	28	2,100	15	30	2,278
Iraq	41	320	2,198	390	210	1,780	50	650	3,080
Irish Free State	64	160	1,917	1,060	500	240	65	170	2,035
Austria	138	118	2,187	981	299	916	141	129	2,403
Algeria	113	91	2,100	1,250	400	320	115	100	2,185
Peru	38	213	1,686	460	580	570	40	220	1,870
Hungary	77	81	1,615	442	445	590	80	90	1,647
Greece	50	34	1,573	370	150	1,000	55	40	1,615
Porto Rico	27	26	1,451	480	70	900	30	30	1,510
Portugal	32	51	1,325	520	460	300	35	60	1,375
Finland	86	79	1,215	682	299	161	64	92	1,298
French Morocco	41	92	1,079	780	110	100	45	100	1,135
Others	868	1,643	31,081	6,942	5,594	17,527	968	1,838	32,869
Total	44,864	166,503	1,510,369	621,863	126,156	617,704	47,429	179,433	1,592,585

Proven Oil Reserves

By V. R. Garfias* and R. V. Whetsel*

(New York Meeting, February, 1936)

It has been repeatedly questioned whether estimates of oil reserves are of any practical value, as the greater number of such calculations previously made have subsequently been proved to be grossly inaccurate. But even admitting partial justification for such statements, it must be evident that some idea, however approximate, of the available reserves of essential minerals—petroleum included—is of vital importance in mapping their development and the future trend of the related industries, particularly if it is kept constantly in mind that these estimates are not only never intended as a final word but must continually be subject to revision in accordance with the changes in their component factors. *The value of these estimates, therefore, hinges on the clear understanding of what is meant by reserves and that the figures can only apply within the limited time when the controlling factors remain unchanged.*

It should be understood, further, that while estimates of *possible* and *probable* oil deposits are as a rule but idle conjectures, appraisals of *proven oil reserves* can undoubtedly be made with an ever-increasing degree of accuracy. And it is with this in mind that in the present study the endeavor has been to estimate only the world's *proven oil reserves* and to leave out of consideration the questionable volume of the *probable* and *possible* oil reserves.

Such a survey presupposes further a clear distinction between the known amount of oil underground in proven fields at any one time, and the *proven reserves:* the portion that can be economically brought to the surface and made available for utilization.

Only a fraction of the petroleum stored underground in proven fields—usually associated with natural gas—is or can be economically brought to the surface, and not all of the oil brought to the surface is economically utilized; also, although practically all the natural gas can be economically recovered and utilized, in actual practice a large part of the total volume that reaches the mouth of the well is wantonly blown into the air and wasted. It is thus estimated that in the United States only some 25 per cent of the petroleum stored underground in proven fields is actually brought to the surface; and in actual practice close to 25 per cent of the total gas produced is now absolutely wasted. And the dissipation of this

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gas, unwarranted as it is, not only diminishes the gas supply but diminishes also the proven reserves of petroleum from such fields as the Panhandle of Texas, where petroleum and natural gas are produced simultaneously.

Many factors affect the estimates of the *proven reserves,* such as the capacity and nature of the reservoir, its depth, the quality of the product, the conservation of natural gas and its efficiency in recovery, the methods of development and recovery, the demand and the price of the crude and its byproducts, etc., etc., but superseding at times all of these—in connection with petroleum and natural gas—is the effect of subsoil ownership on the rate and methods of exploitation of the deposits. It should be a comparatively simple matter to eliminate gas and oil waste and overproduction, and thereby obtain a maximum recovery and thus increase the proven reserves of petroleum and natural gas in a field in Russia, Iran or Iraq, where the subsoil rights are either nationalized or an effective legal control of the underground deposits and the manner of their exploitation can be quickly established. It has been and it is to date, on the other hand, almost an impossible undertaking to intelligently regulate the production of petroleum and natural gas in the United States—the largest producer and consumer of the mineral fuels—where the ownership of these products is based on the paramount right of the individual surface owner to *capture,* within the boundaries of his property, all the oil or gas he can, whether or not the oil was originally under his land and regardless of any damage he may do the field by his rate or methods of production. This unlimited *right to capture* has resulted, among other things, in the blowing daily into the air of over 1,000,000,000 cu. ft. of natural gas in the Panhandle field alone, a very high price for the State of Texas and the United States to pay for the sake of perpetuating these antiquated and destructive laws, which place the rights of the individual above community and national rights and affect national security through the wanton and irreparable destruction of these essential munitions of war. Naturally, a change in the rules of ownership and methods of operation might greatly increase the *proven reserves* in the United States without the discovery of new fields.

The world's production of petroleum from the beginning of commercial production to January, 1936, aggregates over 27 billion barrels, of which the fields in the United States have produced approximately 60 per cent. Proven reserves on January, 1936, on the other hand, are estimated at somewhat under 22 billion barrels, of which the fields of the United States should supply less than 50 per cent under present operating conditions.

These reserves theoretically can supply an average total yearly demand estimated at 1,600,000,000 for 14 years but in actual practice the discovery of new pools is essential if a shortage is to be averted—particularly in the United States—within a much shorter period. It should be kept in mind that the consumption of petroleum and its products in the

United States now is and probably will continue for years to aggregate close to 60 per cent of the world's total demand.

No one can predict the number, location or production of new fields. Some no doubt will be discovered; in fact, *many must be discovered* in the near future in the United States in order to meet demand without greatly increasing imports.

In estimating the probabilities of these new discoveries one must guard against the oft repeated assertion that "there has been and there will always be enough—perhaps more than enough—petroleum to meet demand," even more than against the statement that "a petroleum famine is imminent." The writers are of the opinion that the *present proven petroleum reserves*, particularly in the United States, are inadequately small in relation to expected future demands. What the proven reserves will be at any future time is a matter of conjecture.

It should also be pointed out that the proven reserves outside the United States are as a whole more economically and rationally exploited than in the United States, owing largely to the absence in these countries of the detrimental effect of the operation of the Law of Capture. And it seems therefore reasonable to assume that in the future the United States will depend more and more on foreign fields for its oil supply unless the Law of Capture is to all intents and purposes abolished.

In the United States—by far the most important producer and consumer of petroleum—the rate of discovery of proven reserves in the five-year period 1921 to 1925 was roughly 820,000,000 bbl. annually, compared with the average yearly demand of 650,000,000 bbl. In the following five years the additions to reserves reached the annual figure of nearly 2 billion barrels, or double the average demand of 895,000,000. While during 1931 to 1934 the annual new fields averaged but 580,000,000 bbl., or 290,000,000 bbl. under the amount consumed. Important new discoveries are necessary, therefore, in the near future to compensate for the aggregate depletions.

This illustrates that a table of figures showing proven reserves means little unless such figures are interpreted in the form of declining production from present proven reserves, and such production trend compared to the trend of probable future consumption during a given number of years. Such comparison also gives an indication of the required rate of discovery of proven reserves in order to meet demand. Furthermore, these estimates of *future demand* can be made, if normal conditions prevail, as accurately as the estimates of proven reserves.

Assuming therefore a yearly world demand of some 1,700,000,000 bbl. for, say, 10 years to come, we find that present proven reserves of 23,000,000,000 bbl. can produce only about 1,700,000,000 bbl. annually for one or two years and that new proven reserves of about 15,000,000,000 bbl. must be developed within the next 10 years.

It is with the above limitations in mind that the authors have compiled the accompanying table showing an estimate of the world's *proven oil reserves*, in which a greater degree of accuracy has been possible in estimating the reserves in the fields in the United States and to a lesser extent in the Spanish countries than in some of the European and Asiatic fields. Thus the figures of reserves of Iraq are of necessity less reliable

Proven Oil Reserves
THOUSANDS OF BARRELS

	Production to Jan. 1, 1936			Proven Reserves Jan. 1, 1936		
	Field	State	Country	Field	State	Country
United States			17,593,200			10,575,000
Texas		4,188,300			4,250,000	
East Texas	793,800			1,331,000		
Conroe	56,600			550,000		
Yates	209,600			390,000		
Van	87,100			268,000		
Others	3,041,200			1,711,000		
California		4,418,900			4,100,000	
Kettleman Hills	118,200			1,412,000		
Midway Sunset McKittrick	869,800			162,000		
Ventura	216,600			133,000		
Long Beach	551,800			119,000		
Others	2,662,500			2,274,000		
Oklahoma		3,906,100			700,000	
Pennsylvania, New York		1,002,200			490,000	
Wyoming		400,900			230,000	
Kansas		778,700			195,000	
Louisiana		595,700			250,000	
New Mexico		96,200			100,000	
Others		2,206,200			260,000	
Russia			3,364,200			2,830,000
Iraq			37,900			2,475,000
Iran			641,800			2,150,000
Venezuela			1,159,800			1,350,000
Rumania			663,600			633,000
Netherlands East Indies			679,700			450,000
Mexico			1,801,500			420,000
Colombia			167,500			275,000
Peru			184,700			138,000
British India			253,500			111,000
Argentina			138,000			92,000
Trinidad			115,400			91,000
Others			499,200			375,000
			27,300,000			21,965,000

than those of Venezuela and Mexico, while the estimates of Russian fields, which are more conservative than official figures, are admittedly but rough approximations.

The foregoing notwithstanding, the figures given are believed to represent as a whole a fairly true picture of the volume of proven oil reserves and to illustrate that as a whole they are far from impressive and in individual countries like the United States they are inadequately small.

Chapter IV. Production

Introduction

By James Terry Duce,* Member A.I.M.E.

In order to facilitate interpretation of the data in this chapter, we print the following excerpts from circulars to authors, compiled by Mr. Frank A. Herald when he was Vice Chairman for Production of the Petroleum Division:

Generally in Table 1 the unit for presentation of data is a field. For our purposes a field is defined as the whole of a surface area wherein productive locations are continuous. Such unit commonly includes and surrounds nonproductive areas. Such unit commonly includes a great variety of geologic conditions—several units of continuous productive reservoirs of distinctly different structure and of distinctly different stratigraphy. Therefore it is hoped that our authors will subdivide "field" so as to enable students to make analyses that may have scientific and/or commercial value.

As to each space in the tabulation, it is either (1) not applicable, (2) the proper entry is not determinable, (3) the proper entry is determinable, but not determinable from data available to the author, (4) the proper entry is determinable by the author. In spaces not applicable, the author will please draw horizontal lines; in spaces where the proper entries are not determinable, the author will please insert x; in spaces where the proper entries are determinable but not determinable from data available to the author, the author will please insert y; in spaces where the proper entries are determinable by the author he will, of course, make such entries. Generally, y implies a hope that in some future year a definite figure will be available.

Inability to determine precisely the correct entry for a particular space should not lead the author to insert merely y. Contributions of great value may be made by the author in many cases where entries are not subject to precise determination. In such cases the author should use his good judgment and make the best entry possible under the circumstances. For many spaces, the correct entries represent the opinion of the author (for example, "Area Proved") and in such cases the entries need not be hedged to such extent as in cases where the quantities are definite yet can be ascertained only approximately by the author.

In cases under definite headings but where figures are only approximate, the author may use x. For example, if the total production of a field is known to be between 1,800,000 and 1,850,000, the author may report 1,8*xx*,*xxx*; or if the production is between 1,850,000 and 1,900,000, the author may report 1,9*xx*,*xxx*.

Where a numeral is immediately to the left of x or y, such numeral represents the nearest known number in that position.

As to quantity of gas produced from many fields the question will arise as to whether the figures should include merely the gas marketed or should include also estimates of gas used in operations and gas wasted. Although rough approximations may be involved, our figures should represent as nearly as possible the total quantity of gas removed from the reservoir.

* Geologist, The Texas Company, New York, N.Y.; Vice Chairman for Production, A. I. M. E. Petroleum Division, 1935–1936.

While we have not provided a column for showing the thickness of the productive zone, generally the difference between average depth to bottoms of productive wells and average depth to top of productive zone will represent approximately the average thickness of the productive zone. For fields where this is not true because of unusually high dips, or for other reasons, it is suggested that the authors indicate in their texts the approximate average thickness of the productive zone.

The figure representing net thickness of producing rock should correspond to the total of the net portions of the producing zone which actually yield oil into the drill hole. It is recognized that for some fields the authors can make only rough guesses—so rough that figures would be of no value. In such cases the authors should enter either x or y, whichever is more appropriate. Production per acre-foot will have to be treated, of course, in the same manner for the corresponding fields.

We are particularly anxious to have every author give due consideration to the determination of structural conditions of each oil and/or gas body. Please consider each oil and/or gas reservoir and indicate its structure. The mere fact that a reservoir is on an anticline is not proof that the structural condition affecting the accumulation is anticlinal; for example, an oil and/or gas body limited by the upper margin of a lens on the limb of an anticline is "ML" as to structure. By all means, if the oil body occupies any position in the lens other than its upper limit, please so indicate clearly by footnote, for "ML" means, unless modified, that the accumulation is at the upper part of the lens. In every case where the oil and/or gas body terminates short of the up-dip continuity of the reservoir, please carefully check your evidence and then appropriately record your conclusion. "Terrace," "Nose" and "Syncline" are the only terms in our legend which presume such continuity.

Please note that the heading "Number of Dry and/or Near-dry Holes" is intended to cover only such holes as are within the limits of the defined fields.

In Table 2 are listed the important wildcat wells completed during the year. By the term "important" is meant: wells discovering new fields; wells resulting in the discovery of important extensions to old fields; wells discovering new zones in old fields; wells condemning important areas or resulting in significant stratigraphic information, even if the wells are dry; and exceptionally deep wells. At the foot of this table the total number of wells drilled in each district is given, segregated as to oil wells, gas wells and dry holes. The number of wells drilling on Dec. 31, 1935, are in two divisions, designated as wildcat wells and wells in proven fields.

Footnotes to Column Headings—Table 1

[a] In areas where both oil and gas are produced, unless gas is marketed outside the field, such areas are included in column headed "Oil." Manufacture of casinghead gasoline and carbon black is interpreted as outside marketing of gas.

[b] Production per acre is determined by dividing into the number of barrels of oil the sum of the number of acres assigned to "Oil" plus such number of acres of the total assigned to "Oil and gas" as represents the portion thereof occupied by oil.

[c] Wells producing both oil and gas are classified as "Producing oil only" unless gas from them is marketed off the lease.

[d] W, water; G, gas; A, air; AG, air-gas mixture. Numbers following letters indicate number of injection wells.

[e] Bottom-hole pressures are preceded by "e." All other figures represent pressures at casinghead with well closed.

[f] P, paraffin; A, asphalt; M, mixed.

[g] Cam, Cambrian; Ord, Ordovician; Sil, Silurian; Dev, Devonian; Mis, Mississippian; MisL, Lower Mississippian; MisU, Upper Mississippian; Pen, Pennsylvanian; Per, Permian; Tri, Triassic; Jur, Jurassic; CreL, Lower Cretaceous; CreU, Upper Cretaceous; Eoc, Eocene; Olig, Oligocene; Mio, Miocene; Pli, Pliocene.

[h] S, sandstone; SH, sandstone, shaly; Ss, soft sand; H, shale; L, limestone; LS, limestone, sandy; C, chalk; A, anhydrite; D, dolomite; Da, arkosic dolomite; GW, granite wash; P, serpentine.

Figures are entered only for fields where the reservoir rock is of pore type. Figures represent ratio of pore space to total volume of net reservoir rock expressed in per cent. "Por" indicates that the reservoir rock is of pore type but said ratio is not known by the author. "Cav" indicates that the reservoir rock is of cavernous type; "Fis," fissure type.

[j] A, anticline; AF, anticline with faulting as important feature; Af, anticline with faulting as minor feature; AM, accumulation due to both anticlinal and monoclinal structure; H, strata are horizontal or near horizontal; MF, monocline-fault; MU, monocline-unconformity; ML, monocline-lens; MC, monocline with accumulation due to change in character of stratum; MI, monocline with accumulation against igneous barrier; MUP, monocline with accumulation due to sealing at outcrop by asphalt; D, dome; Ds, salt dome; T, terrace; TF, terrace with faulting as important feature; N, nose; S, syncline.

[k] Information will be found in text as indicated by symbols; A, name of author, other than above, who has compiled the data on the particular field; C, chemical treatment of wells; G, gas-oil ratios; P, proration; U, unit operation; R, references; W, water; O, other information.

Oil and Gas Development in South Arkansas in 1935

By H. K. Shearer,* Member A.I.M.E.

(New York Meeting, February, 1936)

There were no important developments in the oil and gas industry in South Arkansas during 1935. Oil production, totaling 11,138,340 bbl., continued the decline that has been normal since 1925, but the decline from 1934 was only 278,600 bbl., or 2.5 per cent. The principal decline was in the Smackover field, while only the Champagnolle and Garland City fields showed notable increases.

More wells were drilled than in any recent year, with a total of 123 completions. There were 44 oil wells, with a total reported initial daily production of 10,013 bbl., or an average of 227 bbl. per well. Two small gas wells were completed in Union County, where the gas is used locally for pumping and field operations. There were 77 dry holes, of which 28 were in or near oil fields and 49 were wildcats. Active drilling operations declined from 65 at the beginning of 1935 to 41 at the end.

Most of the drilling was done during the first part of the year, especially during the flurry caused by the discovery late in 1934 of the "Taylor" sand production in the Champagnolle field, but the producing area was soon outlined. In November, 1935, the J. E. Crosbie, Inc., No. 1 Sullivant in sec. 12, 17S. 14W., producing 560 bbl. per day at 3175 ft., opened a new sand lens in the eastern part of the field.

The Camden "oil field," discovered in the last week of 1934, remained a one-well field, although four offset tests were drilled, besides a number of others in the immediate vicinity.

Several interesting deep tests were drilled during the year, which added a great deal to the general knowledge of the subsurface formations and the structure of south Arkansas, but were not particularly encouraging as to prospects for the very deep production.

First, the H. L. Hunt, No. 15 E. F. Gregory well in sec. 10, 17S., 14W., in the Champagnolle field, was drilled to a depth of 6911 ft. It penetrated red beds for 2982 ft., from 2943 to 5925 ft., mostly if not entirely of Lower Cretaceous age. There was some anhydrite in the last 135 ft. of red beds. This was followed by 890 ft. of limestone, probably Permian, and the rock salt was struck at 6815 ft. The salt is now generally conceded to be of Permian age. Finding salt in this well strongly indicates

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that the entire oil-producing area of south Arkansas and north Louisiana is underlain by a Permian salt basin, and that the large domelike structures that have proved productive were caused principally by flowage of salt, as well as the small piercement-type salt domes, which are confined to a more limited area. This well had some showings of oil in porous zones in the limestone, but tested salt water after casing was set at 5834 ft. It was plugged back and tested at various other levels before final abandonment.

The Gulf Refining Company's No. 49 Lewis Werner Sawmill Co. in sec. 5, 16S., 16W. was drilled to 7973 ft.; the deepest test ever drilled in Arkansas. It found 3078 ft. of red beds, from 2830 to 5908 ft., including some anhydrite in the last 178 ft. Following this was 688 ft. of Permian (?) limestone to 6596 ft., 35 ft. of red sandy shale, then 857 ft. of rock salt from 6631 to 7488 ft. Below the salt was 57 ft. more of anhydrite, then conglomerates and varicolored shales and sandstones, which may be as early as Mississippian, because nothing resembling the Atoka or Pottsville beds of the Pennsylvanian was found. The well stopped in a black

TABLE 1.—*Oil Production in Southern Arkansas*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres			Total Oil Production, Bbl.				Average Oil Production, Bbl.	
			Oil	Gas[2]	Total	To End of 1935	During 1934	During 1935	Daily Average during Dec., 1935	Per Acre to End of 1935[b]	Per Well Daily during Dec., 1935
1	El Dorado, *Union*	16	8,000	*x*	8,000	45,329,200	712,230	624,230	1,600	5,666	6.7
2	Irma, *Nevada*	15	820	*x*	820	5,624,400	300,780	321,160	865	6,859	10.9
3	East El Dorado[1], *Union*	14	1,420	*x*	1,420	8,627,745	171,130	187,625	530	6,076	8.5
4	Stephens, *Columbia, Nevada, Ouachita*	14	3,000	*x*	3,000	5,537,880	227,020	209,585	620	1,846	3.3
5	Smackover, *Ouachita, Union*	14	25,600	*x*	25,600	351,536,445	8,051,230	7,430,090	19,865	13,732	10.7
6	Heavy oil area	14	16,000	*x*	16,000	300,561,615	7,174,915	6,605,320	17,685	18,785	13.9
7	Light oil area	14	9,600	*x*	9,600	50,974,830	876,315	825,270	2,180	5,310	3.8
8	Bradley, *Lafayette*	11	80	0	80	186,705	0	0	0	2,333	0
9	Lisbon, *Union*	10	2,700	*x*	2,700	6,233,665	136,070	114,970	285	2,309	2.0
10	Champagnolle, *Union*	9	2,000	*x*	2,000	11,631,205	523,965	874,395	2,805	5,816	36.4
11	Mt. Holly, *Ouachita*	7	60	0	60	117,085	0	0	0	1,950	0
12	Urbana, *Union*	6	400	*x*	400	2,955,255	848,755	796,375	2,240	7,388	77.2
13	Garland City, *Miller*	4	300	0	300	1,105,280	444,660	555,410	1,365	3,684	65.0
14	Camden, *Ouachita*	1	10	0	10	24,500	500	24,000	45	2,450	45.0
15	Totals for oil fields		44,390	*x*	44,390	438,909,365	11,416,940	11,138,340	30,220		11.3

[1] Including the Woodley pool and other small producing areas.

[2] El Dorado, Irma, East El Dorado, Smackover, Lisbon and Champagnolle produced large quantities of gas from the tops of structures or the upper edges of sands in earlier years. Most of the gas was wasted, but some was used commercially. Stephens produced some gas from the Nacatoch and Urbana from the 2700-ft. sand.

igneous rock, so hard that rotary drilling was almost impossible. There was some showing of oil in the porous limestone, but a test from 6224 to 6431 ft. showed salt water.

This well is in the Louann section of the Smackover field, or on the west flank of the Smackover structural high. The Lion Oil Refining Co. No. A-9 Hayes, drilled in 1931 in sec. 4, 16S., 15W., and near the high point of the Smackover structure, had 500 ft. less of the Lower Cretaceous red beds section, but penetrated 1289 ft. of salt to the total depth of 7255 ft. without reaching the base. This shows the doming effect, and that the movement must have started in Lower Cretaceous time.

The Benedum and Trees No. 1 Brigham, in sec. 29, 14S., 19W., Ouachita County, north of the Stephens field, was drilled to a depth of 5245 ft. The base of the Trinity red beds was reached at 3645 ft., but there was neither Glen Rose nor basal anhydrite, and no salt. Salt-water sand was reported at 4522 ft., and according to the log the lowest beds reached were sand and sandy lime, which can only be classed as Paleozoic from present knowledge.

The discovery of oil in the Rodessa field of Louisiana in July, 1935, stimulated activity in southwestern Arkansas, especially in Miller,

TABLE 1.—(*Continued*)

Line Number	Total Gas Production in Millions of Cu. Ft.	Number of Oil and/or Gas Wells						Average Depth, Ft.		Oil Production Methods at End of 1935		Pressure, Lb. per Sq. In.[e]
			During 1935		At End of 1935					Number of Wells		
	To End of 1935[2]	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Initial
1	x	1,112	0	7	11	239	239	2,177	2,100 2,550 2,950	0	239	x
2	x	142	0	0	0	70	70	1,179	1,150	0	70	x
3	x	184	4	7	4	62	62	2,180	2,170	0	62	x
4	x	303	2	4	9	188	188	2,110	1,500 2,100	0	188	x
5	x	3,724	3	115	94	1,851	1,851			0	1,851	960–1,100
6	x	y	y	y	82	1,271	1,271	2,025 2,475 2,610	2,000 2,450 2,600	0	1,271	x
7	x	y	y	y	12	580	580	2,025 2,300	2,000 2,275	0	580	x
8	0	6	1	0	1	0	0	2,790	2,785	0	0	x
9	x	356	0	27	6	145	145	2,120	2,100	0	145	x
10	x	215	20	8	6	77	77	2,800 3,030 3,215 3,350	2,780 3,000 3,200 3,340	2	75	1,120
11	0	6	0	0	0	0	0	2,813	2,800	0	0	x
12	x	39	7	2	2	29	29	3,560	2,700 3,550	0	29	x
13	0	25	7	0	4	21	21	2,935	2,925	0	21	x
14	0	1	0	0	0	1	1	1,369	1,356	0	1	0
15	x	6,113	44	170	137	2,683	2,683			2	2,681	

Lafayette and Columbia counties. However, the only well completed before the close of the year was the Joe Modisette, No. 1 Red River Lumber Co. in sec. 21, 19S., 24W., Lafayette County. This was junked and abandoned at 5316 ft., near the base of the Glen Rose anhydrite, but not quite deep enough to test the Rodessa producing formations.

The Haynes Production Corporation's No. 1 Embree Heirs in sec. 9, 20S., 28W., Miller County, was drilling at the end of the year, and has since been abandoned at a total depth of 6514 ft., showing that the Rodessa producing area does not extend across the state line into the extreme southwest corner of Arkansas.

TABLE 1.—(*Continued*)

Line Number	Character of Oil Approx. Average during 1935: Gravity A.P.I. at 60° F. Maximum	Gravity Minimum	Gravity Weighted Average	Sulfur, Per Cent	Base[f]	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.
1	39	30	32	1.0	M	Nacatoch[3]	CreU	S	Por	20	ANL	157	Trinity	3,396
2	16	14	15	2.7	A	Nacatoch	CreU	S	Por	15	AF	25	Trinity	3,735
3	21	17	19	1.8	A	Nacatoch[4]	CreU	S	Por	10	TL	39	Trinity	3,765
4	33	13	28	1.6 2.9	A M	Nacatoch, Buckrange	CreU	S	Por	15 7	NLf	45	Trinity	4,502
5												361		
6	25	17	20	2.2	A	Nacatoch, Graves, Tokio	CreU	S	Por	40	As	x	Permian salt	7,255
7	32	25	26	1.8	M	Nacatoch, Meakin	CreU	S	Por	30	TLf	x	Paleozoic igneous	7,973
8	28	25	27	y	M	Buckrange	CreU	S	Por	5	T?	5	Trinity	3,555
9	38	28	33	1.0	M	Nacatoch	CreU	S	Por	20	ML	18	Trinity	3,509
10	37	18	29	1.1	M	Tokio, Trinity	CreU CreL	S	Por	15	NL	131	Permian salt	6,911
11	32	28	30	y	M	Trinity	CreL	S	Por	7	ML	14	Trinity	3,378
12	20	16	17	2.1	A	Trinity	CreL	S	Por	10	A?	33	Trinity	4,501
13	33	27	31	1.2	M	Trinity	CreL	S	Por	10	ML	31	Trinity	4,519
14	·		17	y	A	Nacatoch	CreU	S	Por	13	F?	5	Trinity	2,500
15												864		

[3] Also small production from the Meakin and Tokio sands.
[4] Two or three wells produce from the Tokio.

TABLE 2.—*Summary of Drilling Operations in Arkansas*, 1935

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	9	32
Number of oil wells completed during 1935	44	0
Number of gas wells completed during 1935	1	1
Number of dry holes completed during 1935	28	49

Developments in the California Oil Industry during the Year 1935

By V. H. Wilhelm,* Member A.I.M.E.

(New York Meeting, February, 1936)

During the first half of the year 1935, the oil industry in California was on a fairly profitable basis, owing mainly to the operation of the Petroleum Marketing Agency. Coincident with the discontinuance of enforced curtailment, California production surged upward from an average of about 500,000 bbl. per day (over the first five-month period) to approximately 625,000 bbl. per day (over the last seven-month period). On Dec. 9 the state production had reached a peak of over 700,000 bbl., a figure that had not been approximated since the early days of voluntary curtailment (Fig. 1).

A price cut was instituted during the last half of August, but had no deterring effect on operators that were determined to take advantage of the breakdown of curtailment and produce to capacity.

New reserve figures, compiled from actual potentials, available after cessation of curtailment, revealed the startling fact that California reserves were rapidly declining. This situation, coupled with the desire among operators to obtain a more equitable price for their dwindling reserves, caused a restoration in November of a portion of the August price slash. A further rise in price was effected in early December, and crude quotations at the end of the year closely approximated those in effect during the first eight months.

At the close of the year, the industry felt confident that the production situation was under control. In all fields where competition is keen because of close spacing, production is gradually declining. In the Los Angeles Basin especially there is no likelihood of a large amount of overproduction, unless a new pool is discovered or deeper drilling reveals a prolific source of crude.

As long as the fields that are operated by a few companies, such as Kettleman Hills, North Belridge, Ventura Avenue, West Coyote, Dominguez, and some others, can be controlled, it is believed that the overproduction problem in California will be solved.

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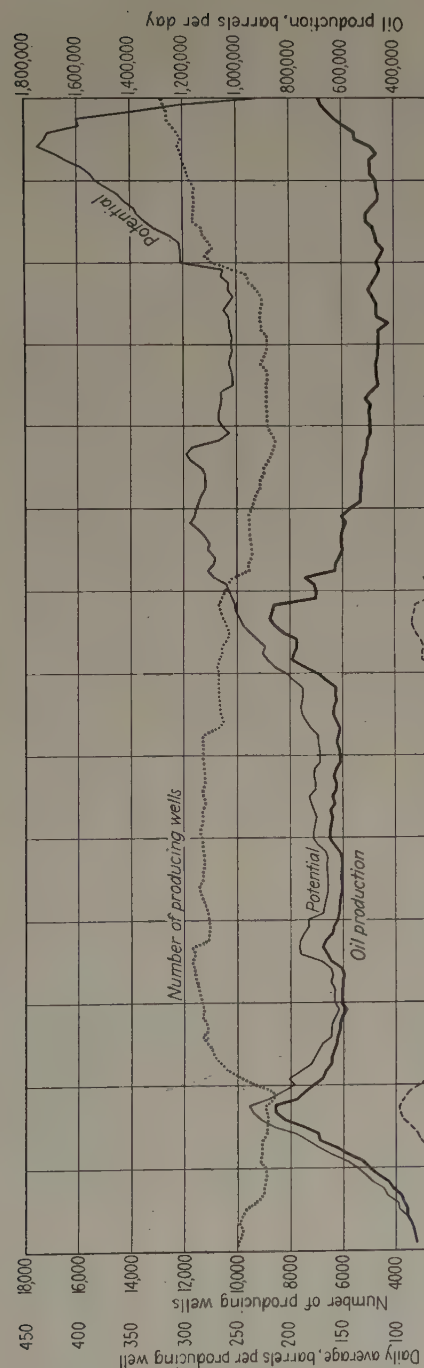
Oil production, barrels per day
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Potential
Number of producing wells
Potential
Oil production
Daily average per producing well
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
18,000
16,000
14,000
12,000
10,000
8000
6000
4000
2000
0
Number of producing wells
450
400
350
300
250
200
150
100
50
0
Daily average, barrels per producing well

FIG. 1.

Developments in Proved Areas

Kettleman Hills North Dome, Kings and Fresno Counties.—Reclassification of participation acreage in this field in April, 1935, resulted in a readjustment of participation boundaries to include an added 300 acres, due mainly to the completion of a Standard Oil Co. well in the extreme northwest end of the North dome, outside of the maximum area of participation line agreed on in February, 1934.

The "gas cap," which originally occupied a large area near the apex of the field, has expanded to the edge in some places, and in numerous instances deep wells are having to contend with rising gas-oil ratios.

During the period of unrestricted oil production this year, gas production exceeded 300,000 M. cu. ft. daily. Recent studies of the gas situation have revealed that the pressure has dropped in some areas as much as 60 per cent from the initial, a condition that warrants a sane program of future production in order that sufficient gas may be conserved to lengthen the flowing period of the wells. Pumping wells of capacity less than 200 bbl. per day will probably be noncommercial in this field.

Lawndale, Los Angeles County.—After some years of inactivity, much property in this area is being leased for deep drilling, owing to the completion, from below 7400 ft., of the Republic Oil Company's El Segundo No. 1A, some distance to the northwest of the previous productive area. This well ceased drilling in basement schist, and is producing from a conglomerate directly overlying this schist.

Because of the exorbitant costs of deep development and the low initial production obtained by the discovery well (250 bbl. per day), it is thought that but few wells will be drilled in this area until crude commands a higher price.

Production overlying basement schist is now being obtained in two fields in the Los Angeles Basin; namely, Playa del Rey and Lawndale, and future wildcat projects undoubtedly will be drilled to basement schist, if possible, before they are considered thorough tests and abandoned.

Long Beach, Los Angeles County.—During the year of 1935 the Long Beach field experienced a drilling boom of unprecedented proportions. Not since the deep-drilling campaign of 1926–28 have there been as many active drillers. This outburst was the effect of the discovery that large wells could be obtained by leasing properties previously disproved by the drill, and directing wells therefrom into productive territory.

This procedure created a difficult situation, as it was necessary for the complainant to prove intentional trespass, as well as definitely to determine the exact subsurface location of the well under observation before court action could be taken. Many of the producing companies, holding proved reserves, united their forces in order to obtain, through devious means, the necessary information that would warrant the court's issuance

TABLE 1.—*Oil and Gas Production in California*

Line Number	Field Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Area Proved, Acres: Oil and Gas[a]	Area Proved, Acres: Gas	Area Proved, Acres: Total
1	1	Alamitos, *Los Angeles*	8¾		110		110
2	2	Athens-Rosecrans, *Los Angeles*	11¾		185		185
3	3	Brea-Olinda, *Orange*	55		1,550		1,550
4	4	Dominguez, *Los Angeles*	12⅓		810		810
5	5	Coyote-East, *Orange*	24¼		785		785
6	6	Coyote-West, *Orange*	30		930		930
7	7	Huntington Beach, *Orange*	15⅓		2,210		2,210
8	8	Inglewood, *Los Angeles*	11⅓		800		800
9	9	Lawndale, *Los Angeles*	7½	730			730
10	10	Long Beach, *Los Angeles*	14½		1,280		1,280
11	11	Los Angeles—Salt Lake, *Los Angeles*	32¾		840		840
12	12	Montebello, *Los Angeles*	18⅚		1,180		1,180
13	13	Playa del Rey, *Los Angeles*	6		640		640
14	14	Potrero, *Los Angeles*	8⅓		60		60
15	15	Richfield, *Orange*	16⅚		880		880
16	16	Santa Fe Springs, *Los Angeles*	16⅙		1,240		1,240
17	17	Seal Beach, *Los Angeles*	9½		400		400
18	18	Torrance, *Los Angeles*	13½		3,650		3,650
19	19	Whittier, *Los Angeles*	33⅔		590		590
20	20	Capitan, *Santa Barbara*	6¼	360			360
21	21	Elwood, *Santa Barbara*	7½		497		497
22	22	Gato Ridge, *Santa Barbara*	4½	540			540
23	23	Moore Ranch, *Santa Barbara*	6				Gas
24	24	Rincon, *Ventura*	8¼		360		360
25	25	San Miguelito, *Ventura*	5⅓		320		320
26	26	Santa Barbara, *Santa Barbara*	6¾	150			150
27	27	Santa Maria, *Santa Barbara and San Luis Obispo*	33⅙		8,060		8,060
28	27-A	Casmalia, *Santa Barbara*	18⅙	1,130			1,130
29	27-B	Cat Canyon East, *Santa Barbara*	24½	} 1,187			} 1,187
30	27-C	Cat Canyon West, *Santa Barbara*	24½				
31	27-D	Edna (Arroyo Grande), *San Luis Obispo*	25⅔	270			270
32	27-E	Huasna, *San Luis Obispo*	6	*y*			*y*
33	27-F	Lompoc, *Santa Barbara*	31½	2,780			2,780
34	27-G	Orcutt, *Santa Barbara*	33⅙		4,620		4,620
35	28	Summerland, *Santa Barbara*	43	180			180
36	29	Ventura Avenue, *Ventura*	19¼		2,120		2,120
37	30	Ventura Newhall, *Ventura and Los Angeles*	71	4,135			4,135
38	30-A	Bardsdale, *Ventura*	41		510		510
39	30-B	Conejo, *Ventura*	41		95		95
40	30-C	Elsmera Canyon, *Los Angeles*	46				
41	30-D	Ex-Mission, *Ventura*					
42	30-E	Hopper Canyon, *Ventura*	48				
43	30-F	Modelo, *Ventura*	37				
44	30-G	Newhall, *Ventura*	37				

[a] Footnotes to column headings and explanation of symbols are given on page 215.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl. To End of 1935	Total Oil Production, Bbl. During 1934	Total Oil Production, Bbl. During 1935	Total Oil Production, Bbl. Daily Average during Nov., 1935	Average Oil Production, Bbl. Per Acre to End of 1935[b]	Average Oil Production, Bbl. Per Well Daily during Nov., 1935	Total Gas Production, Millions Cu. Ft. To End of 1935	Total Gas Production, Millions Cu. Ft. During 1934	Total Gas Production, Millions Cu. Ft. During 1935	Total Gas Production, Maximum Daily during 1935 M. Cu. Ft.
1	[1]	793,506	757,095	2,020	[1]		[1]	[1]	[1]	[1]
2	30,368,253	1,037,817	993,195	2,693	164,153	36	49,394	1,756	1,854	4,649
3	154,197,831	3,744,538	3,611,804	10,235	99,482	28	72,915	3,645	3,556	9,836
4	77,759,762	6,655,465	7,915,850	24,260	96,000	253	119,484	11,148	13,669	50,034
5	75,296,659	907,334	986,705	2,816	95,919	94	37,744	3,298	2,910	9,429
6	68,771,255	3,236,702	3,553,712	10,071	73,948					
7	232,796,006	15,106,268	15,133,293	43,344	105,329	85	225,170	26,281	22,652	99,533
8	96,532,653	3,376,586	4,477,004	14,387	120,668	68	74,080	1,461	1,999	7,117
9	429,316	53,640	64,196	307	588	44	1,111	138	123	357
10	551,807,995	23,067,025	26,562,848	79,711	431,100	63	764,658	20,730	21,598	63,405
11	64,849,274	289,154	292,123	815	77,202	6	*y*			
12	97,325,240	1,980,942	2,287,385	7,032	82,479	38	21,713	313	701	6,176
13	33,358,001	3,187,773	5,695,942	16,756	52,122	81	33,329	2,403	7,561	46,600
14	2,050,476	150,084	135,167	325	34,175	29	1,846	*y*	*y*	
15	77,520,043	2,925,001	2,803,703	7,671	88,091	31	70,155	2,553	2,259	6,352
16	401,778,269	14,722,264	16,158,795	54,293	324,015	86	618,122	13,520	12,033	33,275
17	72,185,996	2,721,951	2,623,431	6,719	141,345	83	79,364	3,570	2,508	10,117
18	80,212,875	2,525,990	2,498,442	6,783	21,976	13	57,605	1,271	1,254	3,493
19	16,645,653	393,476	379,047	1,087	28,213	7	366	*y*	*y*	*y*
20	824,928	194,414	521,528	2,020	2,291	144	203	*y*	203	1,752
21	54,527,220	4,113,644	4,559,588	16,065	109,713	272	44,187	1,392	1,367	9,330
22	(31,084)	(31,084)								
23		Gas					5,034	*y*	*y*	
24	6,513,639	540,886	669,826	2,082	18,093	69	6,573	430	564	1,647
25	1,231,984	268,643	296,286	1,001	3,850	200				
26	2,282,704	598,165	1,144,088	2,232	15,218	34				
27	133,112,292	1,806,106	1,531,370	3,921	16,515	19	30,551	1,814	1,646	5,328
28	*x*	(73,746)	(61,008)	(50)			20	20	*y*	
29	*x*									
30	*x*	(113,186)	(115,766)	(333)			2	2	2	7
31	*x*	(37,339)	(53,131)	(58)						
32	*x*	*y*	*y*	*y*						
33	*x*	(44,550)	(86,459)	(328)						
34	*x*	(1,470,783)	(1,153,913)	(2,860)						
35	3,110,979	20,039	14,499	25	17,283	1				
36	163,223,458	9,882,614	10,979,450	39,493	76,992	176	593,918	39,507	31,610	118,451
37	53,969,682	1,400,039	1,472,471	4,344	13,052	8	380	*y*	380	1,500
38	*x*	(16,751)	(17,622)	(46)						
39	*x*									
40	*x*									
41	*x*	(14,398)	(14,867)	(42)						
42	*x*	(40,235)	(37,454)	(74)						
43	*x*	*y*								
44	*x*	(61,514)	(57,863)	(162)						

[1] With Seal Beach.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells							Drilling Data			
	Completed to End of 1935	During 1935		At End of 1935				Top of Shallowest Zone, Ft.	Top of Deepest Zone, Ft.	Productive Zones, Ft.	Bottom of Deepest Productive Zones, Ft.
		Completed	Abandoned	Temporarily Shut Down	Producing Oil and Gas[c]	Producing Gas Only	Total Capable Producing				
1	[1]	[1]	[1]	[1]	[1]	[1]	[1]	4,635	8,126	2,335	9,026
2	205	1	5	15	76		91	4,120	6,200	2,695	6,815
3	624	2	2	74	375		449	260	3,200	3,940	4,200
4	199	32	1	61	100		161	3,800	5,650	2,400	6,200
5	394	2		11	84		95	2,450	4,000	900	4,100
6		8	1	76	61		137	2,800	5,260	2,101	5,910
7	1,113	18	16	127	510		637	1,900	4,050	2,830	4,730
8	309	23	6	45	220		265	1,100	3,350	2,950	4,100
9	8	1			7		7		5,800	700	6,500
10	2,066	124	89	18	1,269		1,287	2,300	5,470	3,500	8,470
11	1,617		1	13	128		141	475	3,100	1,600	3,500
12	256	10	4	27	183		210	1,730	6,952	2,560	7,012
13	288	42	9	14	208		222	3,350	5,450	1,272	5,730
14	33		2	1	11		12	3,640	6,681	617	6,710
15	399		5	34	249		283	2,900	3,700	1,450	4,550
16	1,049	29	27	52	631		683	3,470	7,500	3,260	7,850
17	237	4	7	31	107		138	4,350	6,200	1,980	7,100
18	883	3	13	22	506		528	2,700		500	3,200
19	290			13	161		174	250	3,900	2,000	4,200
20	26	8	2	9	15		24	1,150	2,510	350	2,580
21	95	11	2	10	64		74	3,164	4,325	410	4,385
22	x	x	x				x	1,750		800	2,550
23	x			4			4		4,139	354	4,493[3]
24	47	1	2	7	29		36	2,500	2,950	650	3,550
25	5	1			5		5		6,472	278	6,750
26	84	21	15	2	67		69	1,965		75	2,040
27	526	4	10	202	211		413	1,200	3,300	700	3,540
28	[2]	x	x				x		3,500	400	3,900
29	[2]	x	x				x	2,800		300	3,100
30	[2]	x	x				x		3,500	200	3,700
31	[2]	x	x				x	800		400	1,200
32	[2]	x	x				x				
33	[2]	x	x				x	2,200		700	2,900
34	[2]	x	x				x				
35	323		4	9	19		28	600	960	345	1,260
36	358	18	3	63	232		295	3,450	8,850	3,000	9,720
37	1,289	7	21	139	552		691				
38	[4]										
39	[4]										
40	[4]										
41	[4]										
42	[4]										
43	[4]										
44	[4]										

[2] With Santa Maria.
[3] Gas.
[4] With Ventura Newhall.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1934: Gravity A.P.I. at 60° F.			Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935		Est. Gross Oil Rerves Jan. 1, 1936, Millions, Bbl.
	Maximum	Minimum	Weighted Average	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.	
1	30	23	26	Pico Puente	Pli Mio	SH		2,335	AF			9,054	[1]
2	40	30	35	Pico	Pli	SH		2,695	A			7,591	6,000
3	28	15	22	Puente	Mio	SH		3,940	AF			8,201	45,000
4	43	26	27	Pico	Pli	SH		2,400	A			8,992	93,000
5	28	18	21	Pico Puente	Pli Mio	SH		900	A			9,084	8,500
6	32	27	29	Pico Puente	Pli Mio	SH		2,100	A			8,144	50,000
7	27	10	23	Pico Puente	Pli Mio	SH		2,830	MF			9,054	89,000
8	29	16	23	Pico	Pli	SH		2,950	AF			6,508	50,000
9	32	26	29	Puente	Mio	Sch. Congl. SH		700	A			7,405	14,000
10	32	20	25	Pico Puente	Pli Mio	SH		3,500	AF			9,280	190,000
11	22	12	15	Pico Puente	Pli Mio	SH		1,600	AF				1,500
12	38	14	26	Pico Puente	Pli Mio	SH		2,560	AF			8,265	37,000
13	26	20	24	Pico Puente	Pli Mio	SH		1,292	A			7,048	30,000
14	45	34	38	Pico	Pli	SH		617	AF			8,376	800
15	28	15	21	Pico Puente	Pli Mio	SH		1,450	A			5,933	22,000
16	36	27	32	Pico Puente	Pli Mio	SH		3,260	A			9,610	80,000
17	30	22	26	Pico Puente	Pli Mio	SH		1,980	AF			7,969	29,000
18	27	14	19	Pico Puente	Plio Mio	SH		500	A			5,938	15,000
19	31	16	24	Pico	Pli	SH		2,000	MF			5,040	3,200
20	44	20	32	Vaqueros Sespe	Mio Oli	SH		350	A			4,071	12,500
21	39	34	36	Vaqueros Sespe	Mio Oli	SH		410	A			7,157	45,000
22	17	14	15	Monterey	Mio	SH		800	Broken shale			6,510	8,500
23		Gas		Vaqueros	Mio	SH		354	AF			6,912	Gas
24	31	25	27	Pico	Pli	SH		650	AF			7,449	5,000
25	30	22	27	Pico	Pli	SH		278	AF			10,030	15,512
26	20	17	19	Vaqueros	Mio	SH		75	MF			4,730	6,000
27	25	9	18					700					30,000
28			9		Mio	SH		400	A				[2]
29	x	x	x		Pli	SH		300	A				[2]
30			14		Pli	SH		200	A			7,199	[2]
31			14		Mio	SH		400	S				[2]
32	x	x	x		Mio	SH			S				[2]
33			19		Mio	SH		700	AF				[2]
34	25	10	17		Mio				AF			5,815	[2]
35	20	11	15	Fernando Vaqueros	Pli Mio	SH		345	AF			5,041	62
36	33	28	30	Pico	Pli	SH		3,000	D			9,846	150,000
37	40	12	x									7,423	25,000
38	x	x	x	Sespe	Oli				A				[4]
39	x	x	x	Vaqueros Fernando	Mio Pli				T				[4]
40	x	x	x	Vaqueros	Mio				A				[4]
41	x	x	x										[4]
42	x	x	12	Monterey Vaqueros	Mio				S				[4]
43	x	x	x	Monterey Vaqueros	Mio				A				[4]
44	x	x	40										[4]

TABLE 1.—(*Continued*)

Line Number	Field Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Area Proved, Acres: Oil and Gas[a]	Area Proved, Acres: Gas	Area Proved, Acres: Total
45	30-H	Pico Canyon, *Los Angeles*	60				
46	30-I	Sespe Canyon, *Ventura*	34		460		460
47	30-J	Shiells Canyon, *Ventura*	24				
48	30-K	Simi Susanna, *Ventura*	23		596		596
49	30-L	Sisar Silverthread, *Ventura*	50				
50	30-M	South Mountain, *Ventura*	19 7/12				
51	30-N	Sulphur Mountain, *Ventura*	8				
52	30-O	Tapo-Eureka, *Ventura*	25				
53	30-P	Temescal, *Ventura*	11				
54	30-Q	Timber Canyon, *Ventura*	50				
55	30-R	Tiptop Fresno Canyon, *Ventura*	17				
56	30-S	Torrey Canyon, *Ventura*	39				
57	30-T	Wiley, *Los Angeles*	48				
58	31	Watsonville, *San Mateo, Santa Clara, Santa Barbara*	49		100		100
59	31-A	Half Moon Bay, *San Mateo*	49				
60	31-B	Los Gatos, *Santa Barbara*	*y*				
61	31-C	Sargent, *Santa Clara*	*y*				
62	32	Belridge, *Kern*	24 3/4		3,200		3,200
63	32-A	Belridge North-Deep, *Kern*	5 1/4		(1,600)		
64	32-B	Belridge North-Shallow, *Kern*	23 1/2				
65	32-C	Belridge South, *Kern*	24 3/4		(1,600)		
66	33	Coalinga East, *Fresno*	35		10,920		10,920
67	34	Coalinga West, *Fresno*	34				
68	35	Coffee Canyon, *Kern*	2 3/4		500		500
69	36	Edison, *Kern*	4 1/4		1,880		1,880
70	37	Elk Hills, *Kern*	17		9,600		9,600
71	38	Fruitvale, *Kern*	7 3/4	1,549			1,549
72	39	Kern Front, *Kern*	23 1/2	3,320			3,320
73	40	Kern River, *Kern*	35 1/2	6,710			6,710
74	41	Kettleman Middle, *Kings*	4		980		980
75	42	Kettleman-North, *Kings and Fresno*	7 1/4		16,670		16,670
76	43	Lost Hills, *Kern*	25 3/4	2,100			2,100
77	44	McKittrick, *Kern*	38	1,060			1,060
78	45	Midway-Maricopa, *Kern*	34 1/2		33,980		33,980
79	46	Mountain View, *Kern*	2 1/2		2,220		2,220
80	47	Mount Poso, *Kern*	9 7/12	1,925			1,925
81	48	Premier, *Kern*	9	1,220			1,220
82	49	Round Mountain, *Kern*	8 1/4	1,340			1,340
83	50	Wheeler Ridge, *Kern*	13 1/2	295			295
84	51	Buttonwillow, *Kern*	6			750	750
85	52	Tulare Lake—Dudley Ridge, *Kern*	6			1,900	1,900
86	44-A	Devils Den, *Kern*	26				*y*
87	45-A	McVan, *Kern*	3 5/6				*y*
88	45-B	Pyramid Hills, *Kern*					
89		Newport, *Orange*	11 5/12				
90		Tracy, *Kern*					*y*
91		Delano, *Kern*					*y*
92		Goleta, *Santa Barbara*	6				*y*
93		Semi-Tropic, *Kern*	1				*y*
94		Total					

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.		Total Gas Production			
							Millions Cu. Ft.			
	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935 M. Cu. Ft.
45	x	(23,650)	(24,108)	(58)						
46	x	(93,819)	(98,661)	(171)						
47	(7,690,109)	(141,005)								
48	x	(40,887)	(44,429)	(113)						
49	x	(57,443)	(61,139)	(158)						
50	(18,421,263)	(720,991)					44,854	2,464	2,388	6,935
51	x	(5,439)	(5,619)	(14)						
52	x	(12,762)	(14,820)	(44)						
53	x	(53,010)	(128,825)	(605)						
54	x	(19,233)	(18,891)	(51)						
55	x	(6,306)	(7,405)	(19)						
56	x	(54,590)	(52,003)	(138)						
57	x	(7,151)	(7,301)	(16)						
58	111,343	21,900	21,825	60	1,113	9				
59	x									
60	x									
61	x									
62	46,525,437	2,927,636	3,629,367	12,681	14,539					
63	(10,686,033)	(2,170,601)	(2,680,432)	(10,200)	(16,596)	64	47,573	5,217	13,929	80,434
64	(15,868,599)	(22,171)	(32,994)	(4)						
65	(19,970,805)	(734,864)	(915,941)	(2,477)	(12,482)					
66	340,545,444	4,255,861	4,954,048	14,300	31,186	21	1,057	43	43	117
67		2,339,089	2,295,369	6,518						
68	With Round Mountain	613,475	582,320	1,410						
69	1,115,061	135,792	979,269	5,349	593	101				
70	135,180,018	3,345,772	3,216,318	9,751	14,081	58	82,858	917	831	2,484
71	8,962,845	1,342,724	1,847,528	6,643	5,786	83				
72	33,470,491	2,434,866	3,035,625	9,750	10,081					
73	267,284,897	1,269,581	1,482,484	4,615	39,834	9				
74	329,029	127,998	38,515		336		8,149	3,822	1,057	13,867
75	118,160,965	21,265,884	27,568,302	110,622	7,088	938	870,458	115.729	121,440	407.153
76	34,144,781	1,463,453	1,761,978	4,818	16,259	15	[9]	[9]	[9]	[9]
77	84,962,024	1,105,618	1,393,985	4,249	80,153	20				
78	784,811,302	19,712,566	20,239,798	59,867	23,096	23	293,470	16,284	14,871	41,963
79	12,071,249	2,609,017	9,228,891	38,583	5,438	357	12,893	1,730	11,083	59,686
80	23,501,828	3,486,217	5,305,474	16,548	12,209	80				
81	296,550	(62,136)	234,414	1,290	243					
82	7,900,347	1,194,847	1,744,831	6,521	4,294	110				
83	3,220,088	15,204	152,846	393	10,847	12	[10]	[10]	[10]	[10]
84	Gas						6,101	7	2,036	18,547
85	Gas									
86	x	(2,927)	(704)							
87	x	(9,034)	(2,252)							
88	x	(4,845)	(13,768)	(23)						
89	129,119		101							
90										
91										
92							[11]	[11]	[11]	[11]
93										
94	4,455,405,261	175,508,566	207,832,131	676,476		53	4,275,337	281,458	298,127	1,119,577

[9] With Belridge.
[10] With Midway-Maricopa.
[11] With Elwood.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells							Drilling Data			
		During 1935		At End of 1935							
	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil and Gas[c]	Producing Gas Only	Total Capable Producing	Top of Shallowest Zone, Ft.	Top of Deepest Zone, Ft.	Productive Zones, Ft.	Bottom of Deepest Productive Zones, Ft.
45	[4]										
46	[4]										
47	[4]							602	2,700	1,800	4,200
48	[4]										
49	[4]										
50	[4]							1,000	2,200	3,200	3,400
51	[4]										
52	[4]										
53	[4]										
54	[4]										
55	[4]										
56	[4]										
57	[4]										
58	27				7		7				
59	[5]										
60	[5]										
61	[5]										
62	831	10		97	200		297				
63		(10)		(17)	(31)		(48)	4,917	8,000	980	8,530
64								2,500	4,000	150	4,100
65				(80)	(169)		(249)	1,000	4,000	570	4,500
66	1,910	9	28	363	982		1,345	100	[8]	420	520
67								100		420	520
68	[6]				30		30	With Round Mountain			
69	76	48	19		57		57	1,114		826	1,940
70	368		5	124	167		291	2,400	3,000	400	3,200
71	98	17	2	3	82		85	3,450	3,600	450	3,950
72	[7]			29	322		351	1,500		275	1,775
73	3,192	44	11	505	1,536		2,041	217		450	767
74	2				2		2		7,563	337	7,900
75	145	35	4	17	122		139	6,070	8,240	2,490	8,560
76	[9]	1	5	47	327		374	300	1,430	520	1,930
77	552	4	6	102	199		301	600	3,500	400	3,700
78	4,348	42	57	917	2,546		3,463	2,500	5,000	2,000	5,500
79	127	69	10		114		114		5,230	310	5,540
80	260	63	18		225		225	1,450	1,605	210	1,755
81	*x*			5	18		23	2,577		113	2,690
82	87	16	2	9	46		55	1,350	1,600	400	1,750
83	39	1	1		34		34	1,700			
84	30	3		6		24	30	2,500	4,200	1,600	5,100
85	9		5	4			4	1,000		150	1,150
86	*x*			3	2		5	300	1,420	75	1,470
87	*x*			1	1		2	1,175		59	1,234
88	*x*										
89	*x*		3								
90	3	2	1			2	2				
91	5	5	3	2			2				
92	2	2		2			2				
93	35	22	12	23			23				
94	24,869	763	439	3,338	13,099	26	16,463				

[5] With Watsonville.
[6] With Round Mountain.
[7] With Kern River.
[8] Lowest Flank 4200′ bottom 4620′.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1934 — Gravity A.P.I. at 60° F.			Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935		Est. Gross Oil Rerves Jan. 1, 1936, Millions, Bbl.
	Maximum	Minimum	Weighted Average	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.	
45	x	x	x		Mio				A				[4]
46	x	x	x										[4]
47	45	17	30	Sespe	Oli			1,800	A		Oligocene	7,423	[4]
48	x	x	x	Sespe	Oli								[4]
49	x	x	x	Monterey	Mio				AF				[4]
				Sespe	Oli								
50	33	19	24	Sespe	Oli			3,200	A			5,922	[4]
51	x	x	x	Monterey	Mio				A				[4]
52	x	x	x	Mecanos	Eoc				A				[4]
				Vaqueros	Mio								
53	x	x	x	Vaqueros	Mio				A				[4]
54	x	x	x	Vaqueros	Mio								[4]
55	x	x	x	Monterey	Mio								
				Sespe	Oli								[4]
56	x	x	x						A				[4]
57	x	x	x		Mio								[4]
58	x	x	x										570
59	x	x	x										[5]
60	x	x	x										[5]
61	x	x	x		Mio								[5]
62													130,680
63				Temblor	Mio	SH		980	A			9,492	
	42	13	27	Wagon Wheel	Eoc								(124,100)
64				Etchegoin	Pli	SH		150	A			11,377	
65	27	17	22	Etchegoin	Pli	SH		570	A				(6,580)
					Mio								
66	34	12	18	Temblor	Mio	SH		420	A				38,850
67	34	12	18	Jacilotos	CreU	SH		420	MUP				13,000
				Temblor	Mio								
				Santa Margarita	Mio								
68	17	16	16	Vaqueros	Mio	SH			FM				14,100
69	28	14	20	Chanag	Pli	SH		826	M			5,003	19,000
				Santa Margarita	Mio								
				Temblor									
70	38	15	27	Etchegoin	Pli	SH		400	A			8,404	193,553
				Kern River									
71	23	15	20	Etchegoin	Pli	SH		450	MF			4,542	34,200
72	17	12	14	Etchegoin	Pli	SH		275	MF				34,725
73	17	12	14	Kern River	Pli	SH		450	MF			5,135	20,000
74	58	52	55	Temblro	Mio	SH		337	A			9,332	20,900
75	66	35	38	Temblor	Mio	SH		2,490	A			10,249	664,198
76	33	14	24	Etchegoin	Pli	SH		520	A			7,858	15,000
77	22	12	17	Etchegoin	Pli	SH		400	AF			6,664	12,000
78	28	12	20	Etchegoin	Pli	SH		2,000	MC			9,753	190,000
				Santa Margarita	Mio								
				Maricopa	Mio								
79	34	25	28	Kern River	Pli	SH		310	MF			8,419	52,350
				Santa Margarita	Mio								
80	17	15	16	Vaqueros	Mio	SH		210	MF			3,130	50,250
81	17	12	14	Etchegoin	Pli	SH		113	MF			2,943	20,800
82	22	16	19	Vaqueros	Mio	SH		400	MF			3,763	28,250
83	25	22	23	Maricopa	Mio	SH			A			7,154	1,270
84		Gas		Tulare	Pli	SS		1,600	D			4,946	Gas
				Etchegoin									
85		Gas		Tulare	Mio	S		150	H			4,310	Gas
86			18	Kreyenhagen	Oli	S		75					[12]
87	17	12	14										[12]
88													[12]
89													
90													
91													
92													
93													
94													2,616,040

[12] With Midway Sunset.

of survey orders. Many months passed before these unethical whipstocking methods were subdued, during which time much drainage was suffered by well located productive acreage.

This field continues to stand out as California's greatest, and at the present time is supporting more active drilling than any other single field in the state.

Lost Hills, Kern County.—All tests for Temblor and Wagon Wheel production in this field below present producing horizons have been disappointing, but it is possible that they have not been properly located. At present there is one well drilling, Standard Oil Company's United No. 1, which will be an adequate test of the deeper zones in this field.

Continental Oil Co. has definitely disproved the existence of productive measures below what was once considered the South dome of Kettleman Hills. That company's Gatchell No. 1 well was drilled to a depth of 7849 ft. and abandoned as a dry hole. This well established definitely that the South dome was merely the north edge of the Lost Hills structure.

Montebello, Los Angeles County.—Although wells that were drilled to the Cruz zone at approximately 7000 ft. in the east end of this field were disappointing, the subsurface data, revealed by drilling operations, served to indicate a rising of Miocene beds to the east and away from the main Pliocene fold. A well drilled by the Universal Consolidated Oil Co. at a point $\frac{1}{3}$ mile easterly from the Cruz zone development, encountered the Miocene about 200 ft. higher than any of the Cruz-zone wells, and was completed at a plugged depth of 5880 ft. for 1500 bbl. of 38° gravity oil per day through a $\frac{42}{64}$-in. bean, in June, 1935.

Five other wells were subsequently located and drilled for this correlative production, three of which have been completed. Complicated faulted conditions have been located both by drill and by seismograph, and it is felt that not until several more wells have been sunk will the exact subsurface conditions be revealed.

Mountain View, Kern County.—Through progressive drilling in this field during 1935, its limits have been extended to include another 600 productive acres, making the present estimated proved acreage about 2200. The northerly and southerly boundaries are fairly well outlined. Further extensions may be made in both easterly and westerly directions.

A well drilled in the northwest area of this field by the Union Oil Co. on its Wible lease, to a depth of 7627 ft., failed to reveal other oil-bearing measures below the Santa Margarita, the present lowermost productive horizon in this vicinity. As this is the third deep-test failure in this field, it appears that the formations below present production do not offer any great opportunity for deeper development.

Premier, Kern County.—Drilling activity in this field during 1935 caused its extension in all directions, and estimates indicate that ultimately it will embrace about 1600 acres of productive territory instead of

750 acres as previously computed. New reserve figures for this field show an increase of 10,000,000 bbl. over those of 1934. The oil is of low gravity (16°), however, the shallow depth to which it is necessary to drill (2800 ft.) in order to obtain the average well production of around 250 bbl. a day makes it a profitable field to produce. The oil measures in this field are of Pliocene age, and occur in a monocline, sealed against a northwesterly southeasterly trending fault with about 150 ft. displacement.

Shiells Canyon, Ventura County.—The completion of The Texas Company's Shiells No. 128 well from a plugged depth of 4081 ft., for an initial of 300 bbl. a day of 36° gravity oil, proved the possibility of obtaining commercial production below the previously productive horizons in this field. This well originally was drilled to a depth of 7423 ft., and encountered the Eocene formation, its original objective, at approximately 5300 ft. No indication of productive measures was found in the Eocene. The best zones of production were located between the depth of 3230 and 3900 feet.

A second well drilled in this area, Bankline Oil Company's Calumet No. 1, located and tested an oil horizon considered equivalent to the zone encountered above 3350 ft. in The Texas Company well. The Bankline well yields about 125 bbl. a day of 36° gravity oil. It is estimated that these two tests have proved an area equivalent to 350 acres for future drilling, and have indicated approximately 11,000,000 bbl. of new reserves.

New Discoveries during 1935

Bartolo Area, Los Angeles County.—A new producing area was opened to the drill upon the completion of Woodward Oil Company's Lapworth No. 1 in July, 1935 from a plugged depth of 3197 ft. for 125 bbl. per day of 28° gravity oil. A second well, 500 ft. southwest of the Woodward well, was completed for 50 bbl. a day from 3172 ft., and indications are that a field of moderate importance may be situated in the vicinity of these two producers. Production is being derived from the transition zone above the Miocene. It is thought that wells of greater potentialities may be obtained by deeper drilling. Subsurface data lead to the assumption that this area may be a further easterly extension of the Montebello field.

Geophysical Prospecting.—Geophysical methods of prospecting for oil and gas accumulations were extensively employed throughout the year, with the result that a few favorable structures were located, some of which were subjected to the drill without having obtained definite results at the expiration of the year.

This medium of endeavor has been most successful in locating structures with gentle dips. Advancement has been made in the interpretation of readings through the plotting of known geologic conditions against those revealed by the use of seismograph.

Two gas fields, which were outlined prior to 1935, chiefly through geophysical methods, were proved by the drill during the year.

Semitropic Gas Field, Kern County.—Numerous tests were drilled and subsequently abandoned in the general vicinity of this field prior to its discovery by the Standard Oil Co. in March, 1935. Most of these tests were located on, or near, the surface axis, although the seismograph and recent correlations through actual drilling operations have indicated that the subsurface axis is at least ½ mile to the east.

The discovery well, which blew in unexpectedly for an estimated 80,000 M. cu. ft. per day of dry gas, caused much excitement, and many had visions of a gas field of large proportions. However, the proved area, although embracing approximately 4800 acres, has a spacing program of one well to 160 acres, owing to the thinness of the productive measures.

The field is unique in that it has been fully outlined and developed by 23 productive wells and 12 abandoned wells in less than four months, and also in that it has but 100 ft. of closure.

Two gas zones are contributing to the production; namely, the First Mya (below 2300 ft.) and the Second Mya (below 3000 ft.), both zones being of Pliocene age.

Tracy Gas Field, Kern County.—This field was discovered in August, 1935, by the Amerada Petroleum Corporation when its F.D.L. No. 2 was completed from 4063 ft. for 35,000,000 cu. ft. of gas daily. The scope of this discovery has not as yet been determined, only three wells having been drilled during the year.

Improvements in Drilling and Production Practice during 1935

Improvements in drilling practice have followed three general lines:

1. Increased use of devices designed to give more technical information regarding wells and boreholes than had previously been available. These include: the Schlumberger dipmeter, Halliburton formation-pressure recorder, the Geoanalyzer, and the Stratagraph.

The Schlumberger dipmeter, by electrical conductivity measurements, determines the direction of formation dip at any point in an uncased hole. Previously oriented cores were necessary for this information. The Halliburton formation-pressure recorder records the changes in formation pressure during formation or shut-off tests. The Geoanalyzer is an automatic recording electrical logging device now in competition with the manual recording Schlumberger electrical logging instrument, the operation of which is well known. The Stratagraph is an electrical logging device capable of detecting shale bodies through the casing in boreholes. It has recently been introduced, and is marketed on a service basis.

2. Practices designed to further economy in drilling reveal nothing new, but demonstrate increased use of unitized rotary-drilling machinery and a trend toward the use of wire-line core bits, especially in prospect wells.

3. Directed drilling has been freed from mystery and is accepted as a routine practice. Minor improvements in this line include more efficient deflecting tools and small-size photographic single shots. These single shots can be readily run through drill-pipe tool joints in present use, especially in conjunction with wire-line drilling.

The most significant trend in improved production practice is the use of devices to assist in obtaining a greater amount of oil.

During the year great interest has centered in the use of pressure bombs to determine the actual productive ability of producing wells. General use of these bombs has in many instances enabled operators to obtain increased production by analyzing pressure conditions of wells and initiating proper remedial action.

Parkersburg pumping units, which are designed to lift greater amounts of fluid, are on trial. They have a straight-line stroke up to 10 ft. The Dual pump, manufactured by the Fluid Packed Co. and recently put on the market, is two pumps in one. This pump actually delivers double quantities of fluid without the necessity of changing surface equipment.

Conclusion

There were no important discoveries during 1935, therefore additions to the reserves were very small—even smaller than during any one of the previous six years. Most of this year's production was obtained from previously developed reserves. Probably more than one-half of the reserves that have been set up for California cannot be developed at a profit, unless the market price for oil is considerably increased. It is probable that the 10,000-ft. well will be a reality only with three-dollar oil. Fields like Mount Poso, where considerable production can be obtained at a shallow depth with very low drilling and lifting costs, are much more profitable than fields such as Ventura Avenue, where drilling costs are the highest in the state.

Within a three year period market demand probably will be greater than the available supply of oil; and the effect of this condition will become apparent long before this period elapses, because the fields in California are never produced to their normal potential capacity. This situation, which the industry has endeavored to accomplish for many years on an artificial basis, is now being brought about by nature in a natural way. The effect should be to promote prosperity. Like the farming industry, the oil industry suffers great loss during periods of oversupply. The prosperous years in the past have been those in which demand was greater than supply.

We expect, during the year 1936, to see greater efforts to increase the recovery of oil from proven areas, and also added interest in developing deeper reserves in proven fields or extensions to existing fields. We anticipate further price increases for petroleum products, with resultant new development in areas where production was considered noncommercial under the range of prices prevalent in the industry during the past 10 years.

Acknowledgments

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Oil and Gas Development in Illinois in 1935*

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(New York Meeting, February, 1936)

Drilling activity increased in Illinois in 1935. There were 34 completions as compared with 26 in 1934 and 18 wells were drilling at the end of 1935. Some large blocks of acreage were leased in Marion and Clay counties near the central part of the Illinois structural basin. Production of oil in the state totaled 4,305,000 bbl., a decrease of 4 per cent from that of 1934 There was some curtailment of production in the early part of 1935 but none after April 30 as shown in the following table.

Period	Percentage Produced of Potential Production (Using September 1934 as Basis)
Jan. 1–Feb. 20	79
Feb. 21–Feb. 25	85
Feb. 26–Feb. 28	79
Mar. 1–Mar. 11	85
Mar. 12–Mar. 31	100
Apr. 1–Apr. 9	80
Apr. 10–Apr. 30	86
May 1–Dec. 31	100

This is equivalent to an average curtailment throughout the year of 5 per cent.

The price of Illinois crude oil at the wells remained constant during 1935 at $1.13 per barrel. A small amount of oil was sold at a lower price, notably from the Dupo field, but to arrive at a value for the state's production there would be little error in assuming an average price of $1.13, giving a total value of $4,864,465.

The following table shows production in Illinois by months in 1935, according to the U.S. Bureau of Mines.

Jan.	332,000	May	382,000	Sept.	370,000
Feb.	295,000	June	358,000	Oct.	391,000
Mar.	370,000	July	377,000	Nov.	369,000
April	338,000	Aug.	379,000	Dec.	344,000

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TABLE 1.—*Oil and Gas Production in Illinois*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres: Oil	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1935	Total Oil Production, Bbl.: During 1934	Total Oil Production, Bbl.: During 1935	Total Oil Production, Bbl.: Daily Average during Nov. 1935
1	Warrenton-Borton, *Edgar*	29	100	0	100	26,500±	730±	550±	1.5
2	Westfield (Parker Twp.), *Clark, Coles*	31	9,000	50	9,050	x	x	x	x
3			850	70	920	x	x	x	x
4			9,000	0	9,000	x	x	x	x
5			1,500	0	1,500	x	x	x	x
6	Siggins (Union Twp.) *Cumberland, Clark*	29	3,580	75	3,655	x	x	x	x
7			3,135	55	3,190	x	x	x	x
8			435	15	450	x	x	x	x
9			855	105	960	x	x	x	x
10	York, *Cumberland*		310	40	350	x	x	x	x
11	Casey, *Clark*	29	1,925	55	1,980	x	x	x	x
12			190	15	205	x	x	x	x
13			400	0	400	x	x	x	x
14			1,525	15	1,540	x	x	x	x
15	Martinsville, *Clark*	28	710	155	865	x	x	x	x
16			15	20	35	x	x	x	x
17			275	35	310	x	x	x	x
18			105	0	105	x	x	x	x
19			170	0	170	x	x	x	x
20			195	0	195	x	x	x	x
21			5	0	5	x	x	x	x
22	North Johnson, *Clark*	28	1,320	20	1,340	x	x	x	x
23			1,115	0	1,115	x	x	x	x
24			160	0	160	x	x	x	x
25			820	5	825	x	x	x	x
26			215	0	215	x	x	x	x
27	South Johnson, *Clark*	28	1,715	65	1,780	x	x	x	x
28			185	5	190	x	x	x	x
29			295	0	295	x	x	x	x
30			1,675	35	1,710	x	x	x	x
31			845	5	850	x	x	x	x
32	Bellair, *Crawford, Jasper*	28	1,300	5	1,305	x	x	x	x
33			1,165	0	1,165	x	x	x	x
34			315	0	315	x	x	x	x
35			910	0	910	x	x	x	x
36	Clark County Division[1]		19,960	465	20,425	50,986,000±	507,000	479,000	1,350
37	Main[2], *Crawford*	29	35,135	515	35,650	x	x	x	x
38			340	0	340	x	x	x	x
39			33,795	510	34,305	x	x	x	x
40			1,000	0	1,000	x	x	x	x
41	New Hebron, *Crawford*	26	1,350	210	1,560	x	x	x	x
42	Chapman, *Crawford*	21	1,045	515	1,560	x	x	x	x
43	Parker, *Crawford*	28	1,310	30	1,340	x	x	x	x
44	Allison-Weger, *Crawford*	y	1,075	20	1,095	x	x	x	x
45	Flat Rock[3], *Crawford*	y	1,375	545	1,820	x	x	x	x
46	Birds, *Crawford, Lawrence*	y	4,370	115	4,485	x	x	x	x
47	Crawford County Division[4]		45,655	1,945	47,600	138,844,000	1,572,000	1,532,000	4,400
48	Lawrence, *Lawrence, Crawford*	29	24,150	1,550	25,700	x	x	x	x
49			5,015	35	5,050	x	x	x	x
50			2,240	0	2,240	x	x	x	x
51			345	1,095	1,440	x	x	x	x
52			15,960	220	16,180	x	x	x	x
53			4,020	200	4,220	x	x	x	x
54			6,950	0	6,950	x	x	x	x
55	St. Francisville, *Lawrence*	y	420	0	420	x	x	x	x
56	Lawrence County Division[5]		24,570	1,550	26,120	217,435,000	1,908,000	1,785,000	5,100

[1] Total of lines 1, 2, 6, 10, 11, 15, 22, 27, 32.
[2] Includes Kibbie, Oblong, Robinson & Hardinsville.
[3] Includes Swearingen Gas.
[4] Total of lines 37, 41, 42, 43, 44, 45, 46.
[5] Total of lines 48 and 55.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cubic Feet				Number of Oil and/or Gas Wells							
									During 1935		At End of 1935				
	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov. 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	275	x	0.18	0	0	0	0	22	0	0	4	8	0	0	8
2	x	x	x	x	0	0	0	1,610	0	5	32	380	0	0	380
3	x	x	x	x	0	0	0	184	0	0	y	y	0	0	y
4	x	x	x	x	0	0	0	1,413	0	y	y	y	0	0	y
5	x	x	x	x	x	0	0	12	0	y	y	y	0	0	y
6	x	x	x	x	0	0	0	995	0	3	y	916	y	0	916
7	x	x	x	x	0	0	0	854	0	0	y	y	y	0	y
8	x	x	x	x	0	0	0	90	0	0	y	y	y	0	y
9	x	x	x	x	0	0	0	192	0	0	y	y	y	0	y
10	x	x	x	x	0	0	0	70	0	0	y	44	y	0	44
11	x	x	x	x	0	0	0	532	0	8	7	506	0	0	506
12	x	x	x	x	0	0	0	41	0	0	y	y	0	0	y
13	x	x	x	x	0	0	0	82	0	0	y	y	0	0	y
14	x	x	x	x	0	0	0	319	0	0	y	y	0	0	y
15	x	x	x	x	0	0	0	213	0	32	y	135	0	0	135
16	x	x	x	x	0	0	0	7	0	y	y	y	0	0	y
17	x	x	x	x	0	0	0	63	0	y	y	y	0	0	y
18	x	x	x	x	0	0	0	21	0	y	y	y	0	0	y
19	x	x	x	x	0	0	0	34	0	y	y	y	0	0	y
20	x	x	x	x	0	0	0	39	0	y	y	y	0	0	y
21	x	x	x	0	0	0	0	1	0	0	0	1	0	0	1
22	x	x	x	x	x	x	x	485	1	0	29	428	y	0	428
23	x	x	x	x	x	x	x	296	0	y	y	y	y	0	y
24	x	x	x	x	x	x	x	32	0	y	y	y	0	y	y
25	x	x	x	x	x	x	x	177	0	y	y	y	y	0	y
26	x	x	x	0	0	0	0	44	1	y	y	y	y	0	y
27	x	x	x	x	x	x	x	533	0	14	1	485	y	0	485
28	x	x	x	x	x	x	x	38	0	y	y	y	y	0	y
29	x	x	x	x	x	x	x	59	0	y	y	y	y	0	y
30	x	x	x	x	x	x	x	401	0	y	y	y	y	0	y
31	x	x	x	x	x	x	x	170	0	y	y	y	y	0	y
32	x	x	x	x	x	x	x	485	0	2	y	407	0	0	407
33	x	x	x	x	x	x	x	309	0	0	y	y	0	0	y
34	x	x	x	x	x	x	x	63	0	0	y	y	0	0	y
35	x	x	x	x	x	x	x	182	0	0	y	y	0	0	y
36	2,554	77	0.4	x	y	y	y	4,944	1	64	73	3,309	y	0	3,309
37	x	x	x	x	x	x	x	7,312	2	131	165	5,375	y	0	5,375
38	x	x	x	x	x	x	x	68	0	y	y	y	0	0	y
39	x	x	x	x	x	x	x	7,134	2	y	y	y	y	0	y
40	x	x	x	x	x	x	x	108	0	y	y	y	y	0	y
41	x	x	x	x	x	x	x	295	0	17	1	180	0	0	180
42	x	x	x	x	x	x	x	193	0	8	y	83	0	0	83
43	x	x	x	x	x	x	x	255	0	0	y	221	0	0	221
44	x	x	x	x	x	x	x	146	0	0	y	72	0	0	72
45	x	x	x	x	x	x	x	281	1	3	3	161	0	0	161
46	x	x	x	x	x	x	x	683	1	3	9	474	0	0	474
47	3,041	121	0.6	x	y	y	y	9,165	4	162	179	6,565	y	1	6,566
48	x	x	x	x	x	x	x	4,383	2	35	6	3,331	y	y	3,331
49	x	x	x	x	x	x	x	1,228	0	y	y	y	y	y	y
50	x	x	x	x	x	x	x	475	2	y	y	y	y	y	y
51	x	x	x	x	x	x	x	243	0	y	y	y	y	y	y
52	x	x	x	x	x	x	x	3,017	0	y	y	y	y	y	y
53	x	x	x	x	x	x	x	684	0	y	y	y	y	y	y
54	x	x	x	x	x	x	x	950	0	y	y	y	y	0	y
55	x	x	x	x	x	x	x	54	0	y	y	45	y	y	45
56	8,849	x	1.5	x	y	y	y	9,164	3	35	6	3,376	y	y	3,376

[b] Footnotes to column heads and explanation of symbols are given on page 215.

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935: Number of Wells: Pumping	Oil Production Methods at End of 1935: Injection into Reservoir[d, 8]	Pressure, Lb. per Sq. In.[e]: Initial	Pressure: Average at End of 1934	Pressure: Average at End of 1935	Character of Oil Approx. Average during 1935: Gravity[13] A. P. I. at 60° F.: Maximum	Gravity: Minimum	Gravity: Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
1	215	159	8		x	x	x	x	x	x	y	y		
2			380		200±	x	x	38.4	28.3	34.0	y	M	x	x
3	376	281	y		x	x	x	y	y	30.0	y	M	x	x
4	446	334	y		x	x	x	y	y	33.5	y	M	x	x
5	2,568	2,265	y		x	x	x	y	y	37.0	y	M	x	x
6			916	A2	x	x	x	(36.9)	27.4	33.0	y	M	x	x
7	465	367	y		x	x	x	y	y	34.0	y	M	x	x
8	562	478	y		x	x	x	y	y	33.6	y	M	x	x
9	590	556	y		x	x	x	y	y	(25.7)	y	M	x	x
10	680	588	44		x	x	x	33.9	30.0	(30.3)	y	M	x	x
11			506	[9]	x	x	x	37.2	27.2	29.2	y	M	x	x
12	358	263	y		x	x	x	y	y	(31.9)	y	M	x	x
13	426	309	y		x	x	x	y	y	(30.1)	y	M	x	x
14	505	444	y		x	x	x	y	y	(33.6)	y	M	x	x
15			135	A2	x	x	x	37.5	30.2	36.8	y	M	x	x
16	411	255	y		x	x	x	y	y	y	y	y	x	x
17	511	449	y		x	x	x	y	y	y	y	y	x	x
18	506	477	y		x	x	x	y	y	y	y	y	x	x
19	1,418	1,340	y		x	x	x	y	y	(38.9)	y	M	x	x
20	1,596	1,553	y		x	x	x	y	y	y	y	y	x	x
21	2,830	2,708	1		x	x	x	y	y	39.6	y	M	x	x
22			428		x	x	x	36.2	27.2	31.0	y	M	x	x
23	486	416	y		x	x	x	y	y	y	y	y	x	x
24	451	314	y		x	x	x	y	y	y	y	y	x	x
25	508	465	y		x	x	x	y	y	y	y	y	x	x
26	554	534	y		x	x	x	y	y	y	y	y	x	x
27			485		x	x	x	35.1	28.5	32.2	y	M	x	x
28	549	392	y		x	x	x	y	y	y	y	y	x	x
29	518	453	y		x	x	x	y	y	y	y	y	x	x
30	570	489	y		x	x	x	y	y	y	y	y	x	x
31	618	598	y		x	x	x	y	y	28.5	y	M	x	x
32			407	AG2	x	x	x	35.6	27.3	33.7	y	M	x	x
33	726	561	y		x	x	x	y	y	32.4	y	M	x	x
34	907	817	y		x	x	x	y	y	y	y	y	x	x
35	920	886	y		x	x	x	y	y	37.0	y	M	x	x
36			3,309	G1 A7 AG13	x	x	x	39.6	25.8	33.0	y		x	x
37			5,375	[10]	425±	y	y	36.8	25.1	33.0	y	M	960	2.5
38	822	508	y		x	x	x	y	y	y	y	y	x	x
39	960	900	y	[11]	425±	x	x	36.8	25.1	32.8	y	M	960	2.5
40	1,416	1,337	y		x	x	x	y	y	y	y	y	x	x
41	975	940	180	G2	x	x	x	35.0	24.3	30.1	y	y	x	x
42	1,015	995	83	AG1	x	x	x	y	y	y	y	y	x	x
43	1,025	1,000	221		x	x	x	y	y	y	y	y	x	x
44	930	912	72		x	x	x	30.4	22.6	29.5	y	y	x	x
45	945	935	161		x	x	x	26.6	20.1	22.5	y	y	x	x
46	950	930	474	A7	x	x	x	34.1	26.5	31.3	y	y	x	x
47			6,566	[12]	425±	x	x	38.6	18.5	32.5	y	M	960	2.5
48			3,331	A1	650±	x	x	39.3	26.7	32.9	y	M	y	2.4
49	1,000	800	y		x	x	x	y	y	y	y	y	x	x
50	1,265	1,250	y		x	x	x	y	y	y	y	y	x	x
51	1,345	1,330	y		x	x	x	y	y	y	y	y	x	x
52	1,430	1,400	y		600±	x	x	y	y	y	y	y	x	x
53	1,580	1,560	y		650	x	x	y	y	y	y	y	x	x
54	1,710	1,700	y		x	x	x	y	y	y	y	y	x	x
55	1,865	1,843	45		600	x	x	37.3	37.3	37.3	y	y	x	x
56			3,376	A1		x	x						x	

[8] Numbers in this column indicate numbers of injection wells.
[9] G1, A3, AG11. [10] G15, A24, AG20, W1. [11] G15, A24, AG20, W1. [12] G17, A31, AG21, W1.
[13] All gravities given (except those in parentheses) were from data for the year 1925 furnished by the Illinois Pipe Line Co. Gravities in parentheses are for particular samples; see Illinois State Geol. Survey Bull. 54 Table 3. The values have been converted from Baumé to A. P. I. gravities.

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935	
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1	Unnamed	Pen	S	Por	*x*	ML	0	Pen	715
2	See below.					D	99	Trenton (Ordo)	2,918
3	Shallow gas sand	Pen	S	Por	36	D	*x*		
4	Westfield lime	MisL	L	Por Cav	*x*	D	*x*		
5	Trenton (Ordo)	Ordo	L	Por	*x*	D	*x*		
6	See below.					D	28	Dev limestone	2,010
7	First Siggins sand	Pen	S	Por	*x*	D	*x*		
8	Second and third Siggins sand	Pen	S	Por	*x*	D	*x*		
9	Lower Siggins sand	Pen	S	Por	*x*	D	*x*		
10	York sand	Pen	S	Por	*x*	AM	2		960
11	See below.					AM	20	MisL	808
12	Upper gas sand	Pen	S	Por	*x*	AM	5		
13	Lower gas sand	Pen	S	Por	*x*	AM	12		
14	Casey sand	Pen	S	Por	*x*	AM	20		
15	See below.					D	5	St. Peter	3,411
16	Shallow sands	Pen	S	Por	*x*	D	1		
17	Casey sand	Pen	S	Por	*x*	D	5		
18	Martinsville sand	MisL	L	Por	*x*	D	1		
19	Carper	MisL	S	Por	*x*	D	1		
20	"Niagaran"	Dev	L	Por	*x*	D	3		
21	Trenton	Ordo	L	Por	*x*	D	1		
22	See below.					AM	16	Mis	965
23	Claypool sand	Pen	S	Por	*x*	AM	12		
24	Shallow sands	Pen	S	Por	*x*	AM	4		
25	Casey sand	Pen	S	Por	*x*	AM	12		
26	Upper Partlow	Pen	S	Por	*x*	AM	16		
27	See below.					AM	29	Mis	1,160
28	Claypool sand	Pen	S	Por	*x*	AM	3		
29	Casey sand	Pen	S	Por	*x*	AM	11		
30	Upper Partlow	Pen	S	Por	*x*	AM	29		
31	Lower Partlow	Pen	S	Por	*x*	AM	10		
32	See below.					AM	14	MisL	1,471
33	"500 Ft." sand	Pen	S	Por	*x*	AM	3		
34	"800 Ft." sand	Pen	S	Por	*x*	AM	3		
35	"900 Ft." sand	MisU	S	Por	*x*	AM	12		
36					33±		213		
37	See below.						200	Trenton (Ordo)	4,620
38	Shallow sand	Pen	S	Por	*x*	ML	*x*		
39	Robinson sand	Pen	S	Por	25±	ML	167	Trenton (Ordo)	4,620
40	Oblong	Mis	S or L	Por	*x*	A, ML	23	Mis	1,479
41	Robinson sand	Pen	S	Por	*x*	ML	5	MisL	2,056
42	Robinson sand	Pen	S	Por	*x*	ML	10	Mis	2,279
43	Robinson sand	Pen	S	Por	*x*	ML	10	Pen?	1,127
44	Robinson sand	Pen	S	Por	*x*	ML	6	Pen	1,041
45	Robinson (Flat Rock)	Pen	S	Por	*x*	ML	8	Pen	1,032
46	Robinson sand	Pen	S	Por	*x*	ML	12	Mis L	1,731
47		Pen, Mis	S	Por		ML	251	Trenton (Ordo)	4,620
48	See below.					A	84	St. Peter	5,190
49	Bridgeport sand	Pen	S	Por	40	A	19		
50	Buchanan	Pen	S	Por	15	A	3		
51	"Gas" sand	MisU	S	Por	15	A	5		
52	Kirkwood	MisU	S	Por	30	A	10		
53	Tracy	MisU	S	Por	20	A	11		
54	McClosky	MisL	L	Por	10	A	24		
55	Kirkwood	MisU	S	Por	22	ML	0	Mis	1,900
56							84	St. Peter	5,190

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov. 1935
57	Allendale, *Wabash*	23	1,670	0	1,670	4,000,000	220,000±	280,000±	760±
58	Southeastern Illinois Field[6]		91,845	3,960	95,805	411,265,000	4,207,000	4,077,000	11,611
59	Colmar-Plymouth, *McDonough-Hancock*	215	2,450	0	2,450	1,987,000	81,000	86,800	407
60	Pike County Gas, *Pike*	30 Abd. 1930		8,960	8,960	0	0	0	0
61	Jacksonville Gas, *Morgan*	25	30	1,290	1,320	2,100	0	0	0
62	Carlinville, *Macoupin*	26 Abd. 1925±	30	50	80	*x*	0	0	0
63	Spanish Needle Creek, *Macoupin*	20 Abd. 1934	0	80	80	0	0	0	0
64	Gillespie-Wyen, *Macoupin*	20 Abd. 1935	40	0	40	*x*	1,095	1,925	5±
65	Gillespie-Benld Gas, *Macoupin*	12	0	80	80	0	0	0	0
66	Staunton Gas, *Macoupin*	19 Abd. 1919	0	400	400	0	0	0	0
67	Litchfield, *Montgomery*	56 Abd. 1904	100	0	100	22,000	0	0	0
68	Collinsville, *Madison*	26 Abd. 1921	40	0	40	715	0	0	0
69	Ayers Gas, *Bond*	13	0	280	280	0	0	0	0
70	Greenville Gas, *Bond*	25 Abd. 1923	0	160	160	0	0	0	0
71	Carlyle, *Clinton*	24	915	0	915	3,261,000±	26,400	39,500	124
72	Frogtown, *Clinton*	17 Abd. 1933	300	0	300	*x*	0	0	0
73	Sandoval, *Marion*	26	770	0	770	2,577,000	34,300±	27,000	74
74	Centralia, *Marion*	25	175	0	175	*x*	*y*	*y*	*y*
75	Wamac, *Clinton, Marion, Washington*	14	250	0	250	330,000±	25,000±	30,000±	70
76	Dupo, *St. Clair*	7 Abd. 1930	670	0	670	824,500	40,200	51,500	132
77	Waterloo, *Monroe*	15	125	0	125	166,000	0	0	0
78	Sparta Gas, *Randolph*	47 Abd. *x*	65	100	165	*x*	0	0	0
79	Ava-Campbell Hill, *Jackson*	18 Abd. 1934	70	370	440	25,000	0	0	0
80	Total Illinois[7]		97,885	15,730	113,615	421,042,000	4,452,000	4,314,000	12,322

[6] Total of lines 36, 47, 56, 57.
[7] Total of lines 58 to 79 inclusive.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cubic Feet				Number of Oil and/or Gas Wells							
	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov. 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Producing Oil and Gas[c]	At End of 1935: Producing Gas Only	At End of 1935: Total Producing
57	2,395	120±	2.3	*x*	*y*	*y*	*y*	407	0	15	*y*	326	*y*	0	326
58	4,510	130±	0.8	*x*	*y*	*y*	*y*	18,953	7	276	257	13,577	*y*	0	13,577
59	811	38	1.6	0	0	0	0	454	4	0	15	256	0	0	256
60	0	0	0	*x*	0	0	0	68	0	0	0	0	0	0	0
61	70	14±	0	*x*	*x*	*x*	*x*	53	0	*y*	*y*	0	0	*y*	*y*
62	*x*	*x*	0	*x*	0	0	0	8	0	0	0	0	0	0	0
63	0	0	0	14.4	0	0	0	7	0	*y*	0	0	0	0	0
64	*x*	*x*	0.6	0	0	0	0	22	0	0	4	8	0	0	8
65	0	0	0	135.8	0	0	0	4	0	4	0	0	0	0	0
66	0	0	0	1,050	0	0	0	18	0	0	0	0	0	0	0
67	220	*x*	0	*x*	0	0	0	17	0	0	0	0	0	0	0
68	*x*	*x*	0	0	0	0	0	5	0	0	0	0	0	0	0
69	0	0	0	80.4	13.4	13.4	*y*	15	0	0	0	0	0	8	8
70	0	0	0	990	0	0	0	4	0	0	0	0	0	0	0
71	3,564±	178±	1.2	0	0	0	0	164	0	0	5	102	0	0	102
72	*x*	*x*	0	0	0	0	0	12	0	0	0	0	0	0	0
73	3,347	167±	2.0	0	0	0	0	122	0	0	9	36	0	0	36
74	*x*	*y*	*y*	0	0	0	0	22	0	2	*y*	3	0	0	3
75	1,320	66	1	0	0	0	0	103	0	2	*y*	70	0	0	70
76	1,230	24	3.4	0	0	0	0	230	3	9	0	38	0	0	38
77	1,328	*y*	0	0	0	0	0	23	0	0	0	0	0	0	0
78	*x*	*x*	0	*x*	0	0	0	20	0	0	0	0	0	0	0
79	35	*x*	0	*x*	0	0	0	35	0	0	0	0	0	0	0
80	4,301		0.8	*x*	*y*	*y*	*y*	20,347	18	289	286	14,090	*y*	8	14,098

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935: Number of Wells: Pumping	Oil Production Methods at End of 1935: Injection into Reservoir[d,8]	Pressure, Lb. per Sq. In.[e]: Initial	Pressure, Lb. per Sq. In.[e]: Average at End of 1934	Pressure, Lb. per Sq. In.[e]: Average at End of 1935	Character of Oil Approx. Average during 1935: Gravity[13] A. P. I. at 60° F.: Maximum	Character of Oil Approx. Average during 1935: Gravity[13] A. P. I. at 60° F.: Minimum	Character of Oil Approx. Average during 1935: Gravity[13] A. P. I. at 60° F.: Weighted Average	Character of Oil Approx. Average during 1935: Sulfur, Per Cent	Character of Oil Approx. Average during 1935: Base[f]	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Character of Gas, Approx. Average during 1935: Gal. Gasoline per M. Cu. Ft.
57	1,460	1,425	326	6W	*x*	*x*	*x*	35.9	24.1	35.1	*y*	*y*	*x*	*x*
58			13,577	G19 A38 AG34 W7				39.3	18.5	33.1			*y*	2.4
59	468	447	256	A63	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*		0
60	275	265	0		*x*	*x*	*x*						*x*	*x*
61	335	330	0		*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	850	*y*
62	398	380	0		135	*x*	*x*	*x*	*x*	27.7	*x*	*y*	*x*	*x*
63	405	385	0		*y*	*y*	*y*						*y*	*y*
64	670	650	8		*x*	*x*	*x*	*x*	*x*	30	*x*	*y*		
65	555	542	0		155	*x*	*x*						788	*y*
66	491	461	0		145	*x*	*x*						*x*	*x*
67	674	664	0		*x*	*x*	*x*	*x*	*x*	21.7	*x*	*y*	*x*	*x*
68	1,400	1,305	0		*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
69	945	940	0		335		310						1,050	0
70	993	927	0		*x*	*x*	*x*							0
71	1,055	1,035	102	W7	*x*	*x*	*x*	37.0	34.2	35.2	*y*	*y*	*x*	*x*
72	957	950	0		*x*	*x*	*x*	*y*	*y*	31.9	*y*	*y*	*x*	*x*
73	1,560	1,540	36		*x*	*x*	*x*	35.1	32.7	34.5	*y*	*y*		
74	1,150	1,130	3		*x*	*x*	*x*	35.0	31.0	32.0	*x*	*x*		
75	760	720	70	W7	*x*	*x*	*x*	30.8	29.3	30.2	*y*	P		
76	651	601	38		*x*	*x*	*x*	*y*	*y*	32.7	*y*	*y*		
77	460	410	0		*x*	*x*	*x*	30.1	29.5	30.0	*x*	*x*		
78	857	850	0		*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
79	798	780	0		115	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
80			14,090	G19 A92 AG34 W18										

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935	
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
57	Biehl sand	Pen	S	Por	20	AM	43	MisL	2,228
58							591		
59	Hoing sand	Dev	S	Por	21	A	0	Trenton (Ordo)	805
60	Niagaran	Sil	L	Por	10	A	0	St. Peter	893
61	Gas sand	Pen, Mis	S, SL	Por	5	ML	8	Trenton (Ordo)	1,390
62	Unnamed	Pen	S	Por	*x*	A	0	Pen	410
63	Unnamed	Pen	S	Por	*x*	D	1	Pen	495
64	Unnamed	Pen	S	Por	*x*	T	14	Trenton (Ordo)	2,560
65	Unnamed	Pen	S	Por	*x*	A	0	Pen	575
66	Unnamed	Pen	S	Por	*x*	A	0	Trenton (Ordo)	2,371
67	Unnamed	Pen	S	Por	*x*	D	0	Pen	681
68	Trenton	Ordo	L	Por	20	ML	0	Trenton (Ordo)	1,500
69	Lindley	MisU	S	Por	5	A	0	MisL	1,150
70	Lindley	MisU	S	Por	*x*	A	0	Mis	1,065
71	Carlyle	MisU	S	Por	20	A	17	Sil	2,620
72	Carlyle	MisU	S	Por	7	D	0	Carlyle *y*	962±
73	Benoist	MisU	S	Por	20±	D	7	Mis	1,732
74	Dykstra, Wilson, Benoist	Pen, MisU	S	Por	20	D, ML	6	MisL	1,779
75	Petro	Pen	S	Por	20	D	0	Benoist	1,484
76	Trenton	Ordo	L	Por Cav	50	A	0	Trenton (Ordo)	819
77	Trenton	Ordo	L	Por	50	A	19	Trenton (Ordo)	845
78	Sparta gas sand	MisU	S	Por	7	D	5	MisU	985
79	Unnamed	MisU	S	Por	18	A	*y*	Dev	2,530
80							664±		

Of the 34 wells completed in Illinois during the year, 19 were wildcats (Table 2) and 15 were in proved areas.

Wells drilled in 1935 that may open new pools were limited to two gas wells (estimated initial daily open-flow capacity 300,000 and 250,000 cu. ft. respectively), and one small oil well (initial daily production 2 bbl.), all in Lamotte Township (parts of T.6N and T.7N., R 11E.) Crawford County (Table 2, Nos. 9, 11 and 7). The gas horizon is a Pennsylvanian sandstone at depths of 600 and approximately 700 ft. respectively in the two wells. The oil well was in the Tracey sand (basal Chester series).

Two other wells (Table 2, Nos. 12 and 1) indicate extensions to old producing areas. One of these (Table 2, No. 12), an oil well in northern Crawford County, was located in one of the numerous "dry" patches interspersed with the productive areas, ¼ mile from the nearest production to the southeast and to the northeast. The other (Table 2, No. 1)

TABLE 2.—*Summary of Drilling Operations in Illinois during* 1935

Wildcats Drilled in 1935

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Pressure, Lb. per Sq. In.	Remarks (Note Dry Holes Here)
		Sect on, Survey	Township, Lat.	Range, Long.					Oil, U.S. Bbl.	Gas, Millions Cu. Ft.	Casing	
1	Bond	NW.SE.25	6 N.	4 W.	957	Ple[1]	Chester	Rea, Evans et al.		0.50	365	
2	Christian	NE.SW.29	12 N.	2 W.	485	Ple	Pen	Nokomis Oil Co.				Dry
3	Coles	SW.NW.21	12 N.	9 E.	1050	Ple	Pen	Richard Eke.				Dry
4	Clinton	NE.NW.30	2 N.	2 W.	1102	Ple	Chester	W. L. Young G. & R. Co.				Dry
5	Clinton	SW.SW.10	2 N.	2 W.	1344	Ple	Chester	Young Bros.				Dry
6	Clinton	SE.NE.35	2 N.	3 W.	1082	Ple	Chester	J. B. Lampen et al.				Dry
7	Crawford	SE.SE.24	7 N.	11 W.	1451	Ple	Ste. Genevieve	Karnes et al.	2			
8	Crawford	NE.NE.25	7 N.	11 W.	888	Ple	Pen	Karnes et al.				Dry
9	Crawford	SW.NW.10	6 N.	11 W.	710	Ple	Pen	Karnes et al.		0.30		
10	Crawford	SW.SE.2	6 N.	11 W.	1010	Ple	Pen	Salvage Oil & Fuel Co.				Dry
11	Crawford	SW.SW.21	7 N.	11 W.	610	Ple	Pen	Karnes et al.		0.25		
12	Crawford	NW.SW.25	8 N.	13 W.	983	Ple	Pen	W .M. Goodman et al.	20			
13	Fayette	NE.SE.17	6 N.	1 W.	1548	Ple	Ste. Genevieve	Hurricane Creek Oil Co.				Dry
14	Greene	NE.NE.17	11 N.	12 W.	953	Ple	Plattin "Trenton"	K. H. Murray Tr.				Dry
15	Hancock	SW.SE.11	4 N.	9 W.	833	Ple	"Trenton"	J. P. Walker				Dry
16	Hancock	SW.cor.33	5 N.	8 W.	755	Ple	Plattin "Trenton"	J. P. Walker				Dry
17	McDonough	SE.NE.31	7 N.	4 W.	546	Ple	Dev	Blandinsville Oil & Gas Co.				Dry
18	McDonough	NW.NE.31	7 N.	3 W.	575	Ple	Dev	J. P. Walker				Dry
19	Monroe	NW.NE.32	3 S.	10 W.	720	Ple	Trenton	Crouch, Alspach et al.				Dry
	Total								22	1.05		

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	4	14
Number of oil wells completed during 1935	12	2
Number of gas wells completed during 1935	0	3
Number of dry holes completed during 1935	3	14

[1] Pleistocene.

is a gas well and indicates a westward extension for about one mile of the Ayers gas field.

Of the 15 wells drilled in proved areas, 12 were oil producers and 3 were dry holes. Six of the 15 wells were in the Colmar-Plymouth field, McDonough County, and of these four were producers having initial productions of 1, 5, 5 and 8 bbl. respectively. In the southeastern Illinois field, which has produced about 97 per cent of the state's production to date, six wells were drilled, including one deepened in Lawrence County, which was dry in the McClosky. One of the remaining five wells in the southeastern Illinois field was in Clark County, two in Crawford County, and two in Lawrence County, initial productions 1, 2, 4, 5 and 40 bbl. respectively. Three new producers were brought in in the Dupo field, St. Clair County, with initial productions of 70, 125 and 40 bbl. respectively. The average initial production of the 14 new producers in the whole state in 1935 was 23 barrels.

With the recent intensification of the search for new oil reserves, the attention of the industry is being directed toward all areas that seem to have any possibility of production. The deeper portion of the Illinois structural basin is now receiving a good deal of attention. The State Geological Survey has made an investigation in this area, the results of which have been published[1]. Independent geological work by certain oil companies has led to the leasing of some large blocks of acreage, and seismograph surveys are now in progress. It seems likely that drilling will be undertaken before long, especially if the geophysical findings appear encouraging.

The third annual petroleum conference of Illinois-Indiana, jointly sponsored by the Illinois-Indiana Petroleum Association, Illinois State Geological Survey, and Indiana Division of Geology, was held June 1, 1935, at Robinson, Ill. Geologic, engineering and economic problems related to the recovery of petroleum in Illinois and Indiana were discussed by various speakers from within and without these states. It is planned to publish papers presented at the conference. Abstracts have already been published in the *Oil and Gas Journal* and were the subject of editorial comment in the *Petroleum Engineer*.

Water-flooding of oil sands to increase the recovery of oil received much attention from Illinois operators. According to a recent study by the Illinois State Geological Survey, the results of which are to be published, there are 12 intentional floods in the Allendale field, Wabash County. In most of these, water from an upper sand is being allowed to flow by gravity into the oil sand through abandoned wells having defective casing. Large increases in oil production in near-by wells have

[1] J. M. Weller and A. H. Bell: Geology and Oil and Gas Possibilities of Parts of Marion and Clay Counties with a Discussion of the Central Portion of the Illinois Basin. Illinois State Geol. Survey *Rept. of Investigations* No. 40 (1936).

resulted in most instances, but in some wells the production has already declined considerably below the peak. The production records of the wells in these flood areas indicate a highly permeable sand and consequent rapid movement of the water and oil through it. The increase of production of the Allendale field from about 220,000 bbl. in 1934 to about 280,000 bbl. in 1935 (a 30 per cent increase) is attributed largely to the action of these water-floods.

The air repressuring operation in the Colmar-Plymouth field, McDonough County, begun on a comparatively small scale in February, 1934, is now one of the largest in Illinois. Upon the completion of arrangements to market the oil at a new small refinery close to the field the large compressors were put in operation July 2, 1935. There are now 63 air-input wells in the whole field, old oil wells being used for this purpose. Air is injected at a pressure of 47 to 50 lb. per sq. in. An appreciable increase in production has resulted (Table 1) but since production in the field was considerably restricted between Jan. 1 and July 2, 1935, this is not a true index to the results obtained. It is expected that the rate of production previous to installation of the repressuring equipment will be increased at least twofold.

Eighteen wells were acidized in Illinois fields in 1935. In seven of these the oil yield was substantially increased; in another seven there was no increase in yield; for the remaining four no data are available. All of the seven wells in which the yield was increased are in Lawrence County and produce from the McClosky "sand" in the Ste. Genevieve oolitic limestone. Of the 11 wells that either gave no increase or for which data are not available, one is in the Casey pool, Clark County, two are "Trenton" wells in the Dupo field, and the remaining eight are McClosky wells in Lawrence County.

Up to date the restricted market for crude oil has discouraged acid treatment of Illinois wells, but with improvement in the economic situation this method of stimulating oil yield will probably find increasing use[1].

Data on the production of natural gas and natural gasoline in 1935 are not yet available. According to the U. S. Bureau of Mines Statistical Appendix to Minerals Year Book, the production of natural gas in Illinois was 1631 million cubic feet in 1933 and 1838 million cubic feet in 1934. The average value in cents per thousand cubic feet at the wells in 1934 was 7.7 and the total value at the wells $144,000. Data concerning natural gasoline from 1930 to 1934 inclusive are given in Table 3.

Production data for oil and gas were furnished by the U.S. Bureau of Mines; the Illinois Pipe Line Co., Findlay, Ohio; the Ohio Oil Co.,

[1] For a discussion of possible areas for acid treatment in Illinois see A. H. Bell: Possible Areas for Acid Treatment in Illinois. Papers on Improved Methods of Exploring for and Recovering Petroleum in Illinois. Illinois State Geol. Survey (1934) 49–52.

Marshall, Ill.; Petro Oil and Gas Co., St. Louis, Mo.; Bond County Gas Co., Greenville, Ill.; and Southwestern Oil and Gas Co., Sandoval, Ill. Mr. William C. Imbt, of the Survey staff, assisted the writer in assembling the statistical data for this report.

TABLE 3.—*Natural Gasoline Produced in Illinois*

Year	Production, Thousands of Gallons	Value		Natural Gas Treated, Millions Cu. Ft.	Yield, Gal. per M. Cu. Ft.
		Total, Thousands of Dollars	Unit, Cents		
1930	6840	420	6.1	2721	2.52
1931	5024	204	4.6	2106	2.39
1932	4558	139	3.2	1924	2.37
1933	3673	194	5.3	1701	2.14
1934	3810	183	4.8	1512	2.52
PRODUCED BY COUNTIES IN 1934					
Clark and Cumberland	391	20		173	2.26
Crawford	1809	91		691	2.74
Lawrence and Wabash	1610	72		648	2.48
State total	3810	183		1512	2.52

Oil and Gas Developments in Indiana in 1935

By J. P. Kerr,* Junior Member A.I.M.E. and W. H. Cordell†

(New York Meeting, February, 1936)

Conditions in the oil and gas industry in Indiana were about the same in 1935 as in 1934. This is especially true of the old Trenton area and the Harrison County area where production was steady and almost no exploration and development took place. The past year has seen an increase in drilling activity and a decrease in oil and gas output in southwestern Indiana.

In the state, 224 wells were completed in 1935, of which 48 were oil wells, 61 gas wells, and 115 dry holes. A few of these were old gas wells deepened to oil horizons. Twenty-six wells started during 1935 were not completed by Dec. 31. Approximately one-half the wells drilled were within proven areas. A relatively large number of wildcats, especially in Daviess, Pike and Gibson Counties, were in search of new gas supplies to supplant the diminishing resources in those counties.

The decreased production of gas was due largely to the fact that existing supplies declined more rapidly than new fields could be brought on. The Alford field, in Pike County, which produced the bulk of the supply in 1934, was called on to do likewise in 1935, but was unable to respond sufficiently to keep up the yearly production for southwestern Indiana. During the last half of the year, the Oaktown field, Knox County, was connected with one of the principal pipe lines of the state, which helped to keep gas production above an unusual low.

The decline in oil production was due almost entirely to proration during the first eight months of the year. The proration affected Daviess, Pike, Gibson, Sullivan and Vigo counties, which produce about three-fourths of the total for the state. After proration was lifted, the wells never quite reached the conditions existing before proration. The average daily production per well in Indiana is less than two barrels.

The outstanding development in Indiana in 1935 was the drilling in the Oaktown field immediately before and after the laying of the 6-in. pipe line to the field. Almost without exception the wells came in with an open flow of two to four million cubic feet. At the end of the year, 26 wells were connected to the pipe line. Development of this field will

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continue into 1936 and this should prove to be the outstanding gas field in the state.

Late in 1935 the discovery well on a gas structure in Anderson township, Perry County, was brought in. Other wells were drilled immediately and now a pipe line is being laid, which doubtless will speed up drilling activities.

In the Francisco gas field, which became almost depleted in 1935, the Henry Erdell No. 1 was deepened 15 ft. and made into an oil well. This resulted in the deepening of other near-by wells with the same result. Doubtless the same success could be encountered in other fields in Indiana.

The discovery well on the St. John's structure in Armstrong township, Vanderburgh County, was drilled during the latter part of

TABLE 1.—*Oil and Gas Production in Indiana*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
1	Trenton, *Many*	49	102,*xxx*	25,*xxx*	65*x*,*xxx*	778,*xxx*
2	Greensburg, *Decatur*	42			19,*xxx*	19,*xxx*
3	Peru, Erie, Rich Valley, *Miami and Wabash*	38	1,6*xx*			1,6*xx*
4	Gifford, *Jasper*	37	5,*xxx*			5,*xxx*
5	Loogootee, *Martin and Daviess*	35	60		100	160
6	Birdseye, *Dubois*	33	*y*	*y*	*y*	*y*
7	San Pierre, *La Porte-Porter*	33	350			350
8	West Princeton, *Gibson*	32	860			860
9	Riley, *Vigo*	29	640			640
10	Arthur (Oakland City), *Pike*	28	700		*y*	7*xx*
11	Harrison County, *Harrison*	25	0	0	6,200	6,200
12	Shelborn-Graysville, *Sullivan*	24	4,1*xx*	3*xx*	1,8*xx*	6,2*xx*
13	Union-Bowman, *Pike-Gibson*	19	2,4*xx*	0	4*xx*	2,8*xx*
14	Alford, *Pike*	16	220	0	870	1,090
15	Oatesville-Wheeling, *Pike-Gibson*	16	1,6*xx*	0	0	1,6*xx*
16	East Princeton, *Gibson*	15	*y*	*y*	*y*	*y*
17	Tri-County, *Pike-Gibson*	10	160	0	80	240
18	Veale, *Daviess*	9	400			400
19	Siosi, *Sullivan*	9	510			510
20	Rock Hill, *Spencer*	7	60			60
21	Troy, *Spencer*	7	75	*y*	*y*	75
22	Francisco, *Gibson*	6		280		280
23	Hudsonville, *Daviess*	6	0	0	4*xx*	4*xx*
24	Bristow, *Perry*	6	120	0	55	175
25	Unionville, *Monroe*	6	0		2,200	2,200
26	Oaktown, *Knox*	5	40	0	720	760
27	Vanderburg, *Vanderburg*	4	250	0	0	250
28	Blairsville, *Posey*	1.7	200	0	0	200
29	Total		12*x*,*xxx*	26,*xxx*	68*x*,*xxx*	83*x*,*xxx*

[a] Footnotes to column headings and explantion of symbols are on page 215.

1935, but adverse weather conditions have caused a delay in further development.

Two wells drilled on the Trinity Springs anticline in Martin County failed to make commercial wells. An interesting wildcat was drilled in Dearborn County, in which a show of oil was reported 700 ft. below the St. Peter sandstone.

To date no controlled water-flooding or repressuring have been attempted in Indiana. Several wells have been treated with acid during the last year, and the results in most instances were considered successful. About 25 per cent of the total oil produced in Indiana is from limestone, so it is reasonable to look for further use of this method of increasing production.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935: Completed	During 1935: Abandoned
1	106,xxx,xxx	20,xxx	21,xxx	x	y	y	0.3	8xx,xxx	19x	200	y	26,5xx	14	51
2								3,1xx	165	194		y	2	1
3	1,5xx,xxx				8xx	x						3xx		
4	2x,xxx				x	x						3xx		
5	2x,xxx	y	y	y	y	y	y	y	7.6	7.7	0.05	46	1	10
6	y				y	y						y		
7	y				y	y						40		
8	1,3xx,xxx	8,0xx	9,7xx	32.3	y	y	0.5	y				148	0	3
9	1xx,xxx				1,2xx	9x						32	0	0
10	y	26,xxx	25,300	95.3	y	y	3	y				259	0	3
11								2,7xx	268	284	y	110	0	5
12	6,5xx,xxx	74,xxx	78,xxx	214.4	y		0.6	1,xxx	49.5	32.3	0.3	1,075	5	8
13	y	150,476	130,837.5	347.5	y		2.4	y	?	28	y	381	8	17
14	25,xxx	2,2xx	3,1xx	8.9	y		1.8	y	703	475	2.5	89	1	6
15	y	222,460	180,300	527	y		2.6					243	3	7
16	y	1,712	1,460	4	y		2					y	0	3
17	94,xxx	17,xxx	22,3xx	66.1	587		3.6	y	y	y	y	73	0	6
18	y	13,167	20,010	74	x	x	3					55	1	2
19	1,901,xxx	172,xxx	154,xxx	922	3,72x		8.5					77	0	4
20	30,xxx	6,5xx	5,980	16	x	x	2.2					16	0	0
21	4x,xxx	16,1xx	13,6xx	40	581		2.5	y	y	y	y	38	0	2
22	37,xxx	6,xxx	10,2xx	33.4		x	5	1,1xx	77	22.5	y	27	3	7
23	0	0	0				y	y	89	189	y	45	4	9
24	41,367	8,736	5,840	16	344		0.76	y	y	y	y	33	0	4
25								12	0	0	0	17	0	0
26	26,xxx	9,xxx	17,011	53	y		10.3	199	18	180	1.6	50	18	0
27	190,641	69,194	66,147	180.6	760		3.1					80	4	2
28	17,xxx	3,xxx	14,xxx	39	y		5.6					13	2	4
29	121,6xx,xxx	817,xxx	778,7xx					8xx,xxx	1,595	1,612	y	y	109	219

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells, At End of 1935: Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[e]	Producing Gas Only	Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Flowing	Pumping	Gas-lift	Air-lift	Misc.	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1934	1935	Character of Oil Approx. Average during 1935, Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	y	2xx	y	5xx	7xx	1,050–1,250	980–1,230	0		0	0	0	325	y	y	38	24	36	y	P
2	40			250	250	907	886						y	125	120					
3						933	898									x	x	x	x	P
4						145	125									21	17	19	1.26	A
5	y	y	0	7	y	540	532						y	y	y					
6						1,008	990						y	y	y	y	y	y	y	P
7						150	125									21	17	19	1.2	A
8	0	64			64	920	890						y	y	y	31	30	30.5	y	P
9	0	0	0	0	0	1,637	1,622									y	y	44	y	P
10	0	32	0	0	32	1,107–1,085	1,126–1,112									y	y	y	y	A
11	9	0	0	39	39	680	650						80	52	y					
12	y	336	0	12	348	325–560	298–545						y	y	y	35	25	31.5	y	M
						667–775	640–730													
						810–2,285	800–2,270													
13	y	156	0	19	175	950–1,250	945–1,244						y	y	y	32	29	31	y	P
14	0	5	0	45	50	1,100–1,140	1,080–1,130						440	150	y	39	36	38	y	M
15	0	194	0	0	194	1,270–1,360	1,250–1,340									y	y	32	y	P
						1,740	1,725													
16	0	2	0	0	2	1,734	1,728									y	y	y	y	P
17	y	24	0	7	31	331–1,335	315–1,317						y	y	y	36	32	34	y	P
18	0	25			25	1,169	1,161									y	y	y	y	y
19	3	49		1	50	2,125–2,194	2,100–2,175											45.9	y	P
20	0	7	0	0	7	1,320	1,310									y	y	36	y	M
21	0	16	0	2	18	728–758	714–747						y	y	y	y	y	34.7	y	P
						827	805													
22	0	5	0	6	11	1,450–1,452	1,430–1,462						590	540	y	y	y	30	y	y
23	0	0	0	16	16	660	650						245	y	y					
24	4	21	0	0	21	350	330						y	y	y	y	y	34.7	y	A
25	13	0	0	0	0	850	800						250	y	y					
26	2	5	0	26	31	610–802	580–790						325	y	y	y	y	32	0.1	P
27	0	57	0	0	57	911–1,031	889–1,007									28	24	26	y	A
28	0	7	0	0	7	1,193	1,168									y	y	27	0.4	P
29	y	1,34x	y	930	2,27x			0	1,3xx	y	y	y								

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1935: B.t.u. per Cu. Ft.	Character of Gas Approx. Average during 1935: Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Porosity[i]	Producing Rock: Net Thickness, Average Ft.	Producing Rock: Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Deepest Zone Tested to End of 1935: Depth of Hole, Ft.
1	950	*y*	Trenton	Ord	D, L	Por Fis	*x*	A	3,8*xx*	Pre-Cam	3,996
2	847	*y*	Trenton	Ord	D, L	Por	*x*	*y*		Pre-Cam	3,055
3			Trenton	Ord	D, L	23	*x*	*y*	*xx*	Trenton	1,041
4			Unnamed	Dev	L	Por Cav	*x*	*y*	*x*	Trenton	1,010
5			Chester	Mis	S	Por	*y*	A	28	Mississippian	783
6			Corniferous	Dev	L	Por	*y*	*y*	*y*	Trenton	1,790
7			Unnamed	Dev	L	*x*	*y*	*y*	*y*	Cambrian	1,996
8			(Brazil) ? West Princetown S.	PenL	S	Por	*y*	A	26	Chester	1,735
9			Corniferous	Dev	L	Por	*y*	*y*	13	Corniferous	1,709
1(			Mooretown-Oakland City	Mis	S	Por	*y*	A	44	Paoli	1,444
11	950		New Albany shale	Dev	Sh	Fis	85	M	39	Trenton	1,770
12	970		Unnamed—1—2—3—4 Niagaran Cypress—950	Pen Sil	S L	Por	*y*	MU,*y*	65*x*	Niagaran	2,328
13			Mooretown—1250	MisU	S, L	Por	*y*	A	67	Paoli	1,632
14	*y*		Oakland City Oil, Brown-G[illegible]	Mis	S	Por	*x*	A	34	St. Louis	1,413
15			Sample-Cypress, Paoli-Oakland City	Mis	S, L	Por	*y*	A	47	Harrodsburg	2,050
16			Chester	Mis	S	Por	*y*	*y*		Chester	2,160
17	*y*		Oakland City	MisU	S	Por	*y*	*y*	33	Mooretown	1,352
18			Ste. Genevieve / Veale Sand	MisU	L	Por	*y*	A	53	Devonian	2,618
19			Niagaran	Dev	S, L	Por	*y*	A*y*	10	Trenton	3,534
20			Bethel?	Mis	S	Por	*y*	MC	8	Miss. lime	1,500
21			Cypress, Mooretown	MisU	S	Por	*y*	*y*	12	Miss. lime	1,708
22	957		Brown sand	MisU	S	Por	*y*	A	6	Ordovician	4,006
23	950	*y*	Barker sand	Mis	S	Por	10	*y*		Ste. Genevieve	1,021
24	*y*	*y*	Cypress, Elwren	Chester	S	Por	*y*	ML	16	St. Louis	710
25	980	0	Corniferous	Dev	D	Por	*y*	A	4	Trenton	2,102
26	950		Staunton, unnamed	Pen	S	Por	*y*	M	15	Chester	1,593
27			Mansfield	Pen	S	Por	*y*	M	22	Glen Dean	1,795
28			Mansfield	Pen	S	Por	30	A	6	Chester	1,920
29											

TABLE 2.—*Summary of Drilling Operations in Indiana*

Important Wildcats Drilled in 1935

	County	Location: Section	Location: Twp., Lat.	Location: Range, Long.	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day: Oil, U.S. Bbl.	Initial Production per Day: Gas, Millions Cu. Ft.	Remarks
1	Pike	24	1 S.	8 W.	1099	Pen	L. Chester	Indiana So. West. Gas Co.		0.8	
2	Posey	23	5 S.	12 W.	1920	Pen	L. Chester	L. R. Henley et al.			Dry hole
3	Vanderburg	30	5 S.	11 W.	1222	Pen	Mansfield	L. R. Henley et al.	30		
4	Vigo	6	10 N.	9 W.	2169	Pen	"Niagaran"	Siosi Oil Co.			Dry hole
5	Pike	18	1 N.	6 W.	745	Pen	L. Chester	Midwest Dev. Corp.		0.75	
6	Martin	17	4 N.	3 W.	1610	Mis	Laurel	Trinity Oil Co.			Dry hole
7	Perry	8	6 S.	3 W.	549	Mis	Cypress	Haney & Hillingsworth		2.25	
8	Dearborn	11	7 N.	2 W.	2020	Ord	Canadian	Dearborn Dev. Co.			Show of oil at 1900 ft.
9	Fountain	24	20 N.	8 W.	1371	Pen	Eden	Hopewell Oil Co.			Dry hole
10	Perry	28	6 S.	1 W.	3212	Mis	St. Peter	Rome Oil Co.			Dry hole
11	Posey	23	7 S.	12 W.	1371	Pen	Mansfield	E. Michel			Dry hole
12	Sullivan	29	7 N.	8 W.	824	Pen	Mansfield	Nelson Bros.		0.5	
13	Warrick	28	4 S.	9 W.	1717	Pen	Paoli	J. Havens et al.			Dry hole
14	Gibson	23	2 S.	9 W.	1480	Pen	Paoli	Midwest Dev. Co.	60		Gas well deepened

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	18	8
Number of oil wells completed during 1935	30	18
Number of gas wells completed during 1935	49	12
Number of dry holes completed during 1935	28	87

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Oil Development and Production of Kansas in 1935

By Howard S. Bryant*

(New York Meeting, February, 1936)

Kansas maintained its fourth position on the list of all oil-producing states, for the ninth consecutive year. Total crude-oil production during 1935, as reported by the *Oil & Gas Journal*, was 53,364,446 bbl. on 97 per cent tank table calculations. This represented an increase of 17 per cent over the production in 1934, which had been the all-time peak of production in Kansas up to that time.

Many of the 51 new discoveries of the year, listed in Table 2, did not have a pipe line outlet until about January, 1936; therefore did not contribute to the 1935 production of the state.

The potential of all wells in Kansas at the end of the year was 998,000 bbl. per day, and the daily allowable was 143,000 bbl. per day, showing proration to the extent of 14 per cent of capacity, under the rules of the State Corporation Commission.

Several important new pipe lines were built into western Kansas by extending older lines from east to northwest, providing additional outlets for new crude-oil production, and increasing the service facilities from the older oil fields.

The crude-oil price level remained unchanged throughout 1935 as it did in 1934, the price of Kansas 36° gravity crude being quoted at $1 per barrel. However, on Jan. 9, 1936, the price of this gravity oil was raised to $1.10 per barrel.

Following the trend of the past several years, drilling activity was largely in western Kansas, and showed a still farther westward push from last year. A relatively high percentage of successful wildcat wells at a relatively shallow drilling depth, combined with the expiration of leased acreage assembled before the depression, caused the rapid exploration and development campaign, begun in 1934, to continue. This has caused the opening of more new fields in 1935 than during any previous year in the history of oil production in Kansas.

A summary of the results of drilling in western Kansas is given in Table 2. Eastern Kansas had considerable drilling, showed six new fields or extensions of oil fields, but in the limited space of this paper such developments cannot be described.

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TABLE 1.—*Oil Production, State of Kansas, Cumulative to Jan. 1, 1936*
(In ranges west and first three ranges east only.)

Line No.	Field	Location, Survey, Township, Range	Producing Horizon	Date of Discovery	Average Depth, Ft.
	Barber County				
1	Whelan	32–31–11W.	"Chat"	Aug. 1934	4,388
	Barton County				
2	Albert	30–18–15W.	Basal sand	Feb. 1935	3,600
3	Beaver	9 and 16–16–12W.	Basal "Siliceous"	Dec. 1934	3,353
4	Davidson	4–16–11W.	"Siliceous"	March 1930	3,340
5	Eberhardt	14–19–11W.	"Siliceous"	June 1935	3,350
6	Ellinwood	9–20–11W. et al.	"Siliceous"	July 1932	3,334
7	Feist	29–18–11W.	Basal "Siliceous"	Oct. 1935	3,430
8	Heizer	16–19–14W.	Oswald		3,255
9	Isern	1 and 12–20–11W.	"Siliceous"	Oct. 1931	3,329
10	Lanterman	15–19–11W.	"Siliceous"	Jan. 1935	3,350
11	Peter	24–20–11W.	"Siliceous"	Oct. 1935	3,280
	Edwards County				
12	McCarty	30 and 31–25–17W.	Cong. (Pen)	May 1929	4,545
	Ellis County				
13	Bemis	16–11–17W.	Topeka L	Oct. 1935	3,035
14	Ruder	8 and 17–15–18W.	Oswald and "Siliceous"	Aug. 1935	3,275 to 3,580
15	Shutts	20 and 32–11–17W.; 5–12–17 W. et al.	Oswald, Cong. and "Siliceous"	Nov. 1928	3,428 to 3,683
16	Victoria	3–14–17W.	Oswald	Dec. 1935	3,300
17	Yocemento	9–13–19W.	Oswald	June 1929	3,600
	Ellsworth County				
18	Becker	25 and 26–17–10W.	"Siliceous"	Sept. 1935	3,270
19	Breford	7–17–10W. et al.	Oswald and Quartzite	Sept. 1932	3,040 to 3,407
20	Heiken	25 and 26–17–10W.	"Siliceous"	Oct. 1930	3,234
21	Lorraine	14–17–9W. et al.	"Siliceous"	Nov. 1934	3,195
22	Lorraine (South)	26–17–9W.	"Siliceous"	April 1935	3,180
23	Stoltenberg	21–16–10W. et al.	"Siliceous"	June 1931	3,347
24	Stratman	1 and 12–17–10W.	"Siliceous"	March 1931	3,271
25	Wilkins	13–17–10W. et al.	"Siliceous"	Apr. 1934	3,390
	Harvey County				
26	Halstead	36–22–2W.	"Chat"	Apr. 1930	3,000
27	Halstead (South)	11–23–2W.	"Chat"	Aug. 1928	3,000
28	Hesston	5 and 8–22–1W.	Misener sand	Aug. 1934	3,320
29	Hollow-Nikkel	33–21–3W. et al.; 19–22–3W. et al.	Oswald, "Chat" Hunton L, Wilcox sd., "Siliceous"	Dec. 1931	3,180 to 3,600
30	Sperling	14 and 23–22–1W.	Hunton L	Jan. 1935	3,340
31	Schowalter	6–22–1W. et al.	Hunton L	April 1935	3,320
	Kingman County				
32	Kingman	16–27–7W.	"Chat"	Jan. 1926	3,876
33	Cunningham	30–27–10W. et al.	Oswald	Jan. 1931	3,450
	McPherson County				
34	Chindberg	13–19–3W. et al.	"Chat"	Sept. 1932	3,025
35	Chindberg (K.C. L)	13–19–3W.	K.C. L	July 1935	2,335
36	Graber	29–21–1W. et al.	Hunton L	May 1934	3,290
37	Johnson	35–19–3W. et al.	"Chat"	Feb. 1932	3,000
38	McPherson	31–18–2W. et al.	K.C. L, and "Chat"	March 1928	2,600 to 3,000
39	Ritz	Tp. 19 and 20 S., R. 1 and 2W.	"Chat," Viola, and Wilcox	July 1929	2,950 to 3,450
40	Voshell	Tp. 20–3W. and 21–3W.	"Chat," Viola, Wilcox, and "Siliceous"	Aug. 1929	3,000 to 3,400
41	Wenger	2–20–1W.	Viola L	May 1935	3,360
	Marion County				
42	Hillsboro	7–19–3E. et al.	Viola L	Oct. 1928	2,805
	Ness County				
43	Aldrich	7–18–25W.	Viola L?	Oct. 1929	4,428
	Reno County				
44	Abbyville	24–24–8W. et al.	K.C. L	Jan. 1927	3,540
45	Burrton (Chat)	Tp. 23 and 24 S., R. 3 and 4W.	"Chat"	Feb. 1931	3,400
46	Burrton (Hunton)	Tp. 23–4W.	Hunton L	March 1934	3,600
47	Burrton (Sil.)	11–23–4W.	"Siliceous"	Jan. 1935	3,784
48	Griffith	4–26–4W.	Viola L	May 1927	4,123

TABLE 1.—(*Continued*)

Line Number	Number Wells Producing 12-31-34	1934 Production, Bbl.	Number Wells Producing 12-31-35	1935 Production, Bbl.	Total Production to 1-1-36	Average Gravity	Pool Potential Rev. as of 1-1-36	Remarks
1	1	4,054	1	16,945	20,999	27	168	
2			1	13,186	13,186	38	29	
3	1	1,940	5	109,902	111,842	38	2,080	
4	1	0	1	0	3,500	38		No pipe line outlet. Produced for fuel only. No official potential. Estimated potential 200 bbl.
5			1	659	659	38	162	
6	12	299,232	15	366,990	749,376	46	3,352	Drilling plan, one well to 40 acres.
7			1	0	0	39	435	No pipe line outlet during 1935.
8	1	40	1	2,876	2,916	48	28	
9	4	147,033	6	220,096	508,969	46	5,419	
10			1	9,988	9,988	38	100	
11			2	9,711	9,711	43	2,132	
12	2	4,354	1	3,326	85,002	35	15	
13			1	0	0	29	631	No pipe line outlet.
14			2	0	0	34 to 42	2,138	No pipe line outlet during 1935.
15	12	164,865	11	166,866	1,043,821	33	1,901	
16			1	306	306	36	928	
17	1	118	Abandoned 1935		60,891	32		Total number producers drilled, 4.
18			2	10,055	10,055	39	260	
19	7	109,985	7	136,666	388,093	45	787	
20	4	61,511	5	48,256	217,929	39	203	
21	1	189	68	1,621,000	1,621,189	46	102,765	
22			5	88,315	88,315	46	4,257	
23	16	614,617	16	458,919	1,632,172	44	2,891	
24	18	352,606	18	187,387	1,542,623	48	771	
25	3	32,279	3	45,442	77,721	41	278	
26	2	31,219	1	20,946	227,173	35	100	Total number producers drilled, 4.
27	Abandoned November 1929				2,725			
28	2	3,354	2	6,363	9,717	40	23	
29	155	5,475,223	130	2,833,626	13,761,867	43	13,604	Nikkel pool of southern McPherson County, formerly carried separately. Now combined with Hollow pool, Harvey Co.
30			4	41,183	41,183	35	395	
31			2	19,523	19,523	35	368	
32	Abandoned September 1927				27,000			Only one producer drilled.
33	24	469,843	34	295,877	1,003,304	36	4,406	
34	8	166,945	21	300,863	470,334	37	1,893	
35			1	6,229	6,229	37	78	
36	2	38,821	4	166,214	205,035	41	2,877	
37	22	508,985	20	313,369	1,570,805	37	1,520	
38	10	32,762	28	143,605	408,584	37	1,091	
39	268	4,579,485	256	2,966,950	24,552,533	37	16,215	Includes Vogts pool in secs. 8 and 9-20-1W.
40	117	2,409,807	120	1,666,186	18,979,528	42	8,140	
41			1	1,438	1,438			Abandoned August, 1935, only one producer drilled.
42	12	156,248	13	127,239	1,350,823	42	753	
43	1	0	1	2,618	9,909	33		No official potential
44	3	52,077	4	78,193	182,614	37	589	
45	63	1,362,832	105	1,838,580	4,239,465	37	23,295	Includes Haury and Stone pools formerly carried separately.
46	37	755,564	107	5,532,923	6,288,487	42	62,797	Includes Haury (Hunton Ls) pool, formerly carried separately.
47			1	22,862	22,862		473	
48	Abandoned 1927				1,480			Development in Hilger pool is rapidly approaching the location of the one well in the Griffith, indicating it may be an edge location of the Hilger pool.

TABLE 1.—(*Continued*)

Line No.	Field	Location, Survey, Township, Range	Producing Horizon	Date of Discovery	Average Depth, Ft.
49	Haven	30–24–4W.	"Chat"	Sept. 1935	3,405
50	Hilger	4, 9 and 16–26–4W.	Viola L	March 1934	4,065
51	Lerado	10 and 11–26–9W.	Viola L	Dec. 1935	4,145
52	Tonn	17–25–4W.	"Chat"	June 1930	3,600
53	Yoder	34–24–5W.	"Chat"	Oct. 1935	3,500
	Rice County				
54	Brandenstein	10–19–10W.	Oswald	Nov. 1933	3,026
55	Chase	16–19–9W. to 13–20–10W.	"Siliceous"	March 1931	3,289
56	Galt	8–18–7W.	"Siliceous"	Oct. 1935	3,220
57	Geneseo	25–18–8W.	"Siliceous"	May 1934	3,175
58	Gouldner	16–18–9W.	"Siliceous"	July 1935	3,228
59	Keesling	10 and 15–20–9W.	"Siliceous'	April 1935	3,260
60	Orth	27–18–10W.	Quartzite	July 1932	3,238
61	Ploog	33–18–9W.	"Siliceous"	July 1930	3,252
62	Raymond	21–20–10W. et al.	Oswald, and "Siliceous"	July 1929	3,100 to 3,350
63	Rickard	22–18–9W.	Simpson sand	Sept. 1935	3,300
64	Silica	31–19–10W. et al.	"Siliceous"	Feb. 1932	3,324
65	Stumps	4 and 5–18–10W.	"Siliceous'	May 1935	3,240
66	Welch	2–21–6W. et al.	"Chat"	April 1924	3,375
67	Wenke	7–20–10W.	"Siliceous"	Mar. 1935	3,370
68	Wherry	2–21–7W. et al.	"Chat"	Sept. 1933	3,380
	Rooks County				
69	Dopita	31–8–17W. et al.	Oswald, and "Siliceous"	Aug. 1934	3,200 to 3,419
70	Laton	11–9–16W. et al.	Oswald	July 1927	3,125
71	Webster (Sil.)	21–8–19W.	"Siliceous"	Oct. 1930	3,445
72	Webster (Osw.)	15–8–19W.	Oswald	Sept. 1934	3,225
73	Zurich	26–10–19W.	Oswald	Sept. 1935	3,340
	Rush County				
74	Greenawalt	17–19–16W.	"Siliceous"	Aug. 1931	3,867
75	Otis	10–18–16W.	Basal sand	July 1934	3,536
	Russell County				
76	Atherton	30–13–14W. et al.	Oswald and "Siliceous"	July 1935	3,000 to 3,285
77	Berrick	6–15–13W.	Oswald	Dec. 1935	2,945
78	Big Creek	30–14–14W. and 36–14–15W.	Oswald and "Siliceous"	July 1935	3,170
79	Boxberger	36–15–15W.	Oswald	Dec. 1935	3,151
80	Bunker Hill	31–13–12W.	Oswald	Oct. 1935	3,000
81	Cram	11–14–15W.	Oswald	July 1935	3,130
82	Dillner	35 and 36–13–15W.	"Siliceous"	May 1930	3,309
83	Donovan	10–15–15W.	Oswald	Feb. 1935	3,191
84	Dubuque	34–15–12W.	"Siliceous"	Oct. 1935	3,275
85	Eichman	34–15–13W. et al.	"Siliceous"	May 1935	3,331
86	Fairport	Tp. 11, 12, and 13 S., R. 15 and 16W.	Oswald, "Siliceous" and Basal sand	Nov. 1923	2,950 to 3,300
87	Fink	16–14–14W.	Oswald	Jan. 1935	3,170
88	Freed	34–14–13W.	Basal "Siliceous"	Mar. 1935	3,306
89	Gideon	8–15–14W.	Oswald	June 1930	3,325
90	Gorham	Tp. 13 and 14–15W.	Oswald and Basal sand	Oct. 1926	3,065 to 3,317
91	Gurney	23 and 26–14–14W.	Oswald	Feb. 1935	3,005
92	Hall (Osw.)	30 and 31–14–13W.	Oswald	May 1931	3,000
93	Hall (Sand)	30–14–13W. et al.	Basal sand	Apr. 1935	3,159
94	Karst	27–15–14W.	"Siliceous"	Oct. 1935	3,315
95	Milburger	7–14–14W.	Basal sand	May 1935	3,315
96	Niedenthal	23–14–15W. et al.	"Siliceous"	Aug. 1934	3,175
97	Ochs	23–15–14W. et al.	"Siliceous"	Oct. 1929	3,370
98	Russell (Osw.)	27–13–14W. et al.	Oswald	Aug. 1934	3,195
99	Russell (Sil.)	27–13–14W. et al.	"Siliceous"	Feb. 1934	3,280
100	Sellens	26–15–13W. et al.	Topeka L, Oswald, "Siliceous"	June 1929	3,100
101	Sullivan (Topeka)	2–14–15W.	Topeka L	May 1935	2,780
102	Sullivan	2–14–15W. et al.	Tarkio, Oswald, "Siliceous"	March 1935	2,450 to 3,310
	Saline County				
103	Olson	10–16–3W.	Viola L	Dec. 1929	3,333
	Scott County				
104	Shallow Water	15–20–33W.	Mississippian L	Dec. 1934	4,680

TABLE 1.—(*Continued*)

Line Number	Number Wells Producing 12-31-34	1934 Production, Bbl.	Number Wells Producing 12-31-35	1935 Production, Bbl.	Total Production to 1-1-36	Average Gravity	Pool Potential Rev. as of 1-1-36	Remarks
49			1	8,127	8,127	40	368	
50	2	47,048	3	66,164	113,212	44	1,544	
51			1	9,186	9,186	42	4,502	
52		Abandoned February 1932			5,877			
53			1	2,867	2,867	36	176	
54	2	137,841	2	96,235	236,611	42	940	
55	100	2,759,381	178	5,044,759	8,683,644	45	52,891	Includes Beyer, Grove and Sharpe pools, formerly carried separately. Of this total 1379 bbl. was K.C. Ls oil produced from discovery well of Grove pool, before being deepened to "Siliceous."
56			1	1,132	1,132	37	387	
57	3	59,154	4	264,692	323,846	39	6,295	
58			2	35,588	35,588	45	1,526	
59			17	238,265	238,265	42	19,777	
60	5	110,301	5	80,875	257,764	42	508	One producer abandoned and one added during 1935.
61	2	51,259	8	218,887	597,024	47	5,247	
62	30	786,738	41	1,012,971	3,149,042	41	11,598	
63			1	4,014	4,014	47	155	
64	2	34,866	40	634,356	677,701	42	56,147	Formerly known as Steckel pool.
65			4	44,550	44,550	43	2,185	
66	29	290,429	31	295,615	3,414,689	32	1,793	
67			2	11,646	11,646	35	136	
68	3	56,115	4	98,437	160,951	42	713	Formerly known as Thode pool.
69	1	0	2	2,106	2,106	25 to 36	597	No pipe line outlet. Produced for fuel only.
70	3	17,090	3	8,519	157,704	30	34	Total number producers drilled, 4.
71		Abandoned October 1932			35,972	25		
72	1	1,477	1	0	1,477	35	264	No pipe line outlet 1935.
73			1	0	0	36	474	No pipe line outlet 1935.
74	1	300	Abandoned January 1935		5,952	43		
75	1	4,009	1	2,247	6,256	35	15	
76			2	0	0	31	733	No pipe line outlet 1935.
77			1	0	0	39	128	No pipe line outlet 1935.
78			2	0	0	35	391	No pipe line outlet 1935.
79			1	0	0	37	884	No pipe line outlet 1935.
80			1	0	0	39	274	No pipe line outlet 1935.
81			1	0	0	35	207	No pipe line outlet 1935.
82	2	11,047	0	2,622	61,017	30		Abandoned May 1935
83			1	0	0	41	233	No pipe line outlet 1935.
84			2	0	0	40	1,002	No pipe line outlet 1935.
85			6	0	0	36	3,166	No pipe line outlet 1935.
86	133	1,410,831	140	1,010,789	11,055,869	38 to 42	4,890	
87			1	1,280	1,280	40	15	
88			1	7,138	7,138	36	15	To be combined with Russell (Sil.) pool in 1936.
89	1	10,946	1	6,442	18,950	36	25	
90	42	528,662	67	1,059,806	3,805,153	34 to 38	17,606	
91			3	1,678	1,678	38	1,680	
92	2	34,995	4	29,315	109,258	38	2,045	
93			6	104,697	104,697	36	541	
94			1	0	0	36	287	No pipe line outlet.
95			1	1,406	1,406	35	187	Tank-wagon sales, only, during 1935.
96	3	0	11	244,646	244,646	40	5,006	
97	10	159,430	9	228,176	510,845	36	1,477	
98	2	24,147	3	88,847	112,994	38	1,189	
99	12	190,422	30	997,532	1,187,954	35	22,226	
100	14	207,122	19	351,773	1,182,760	37	3,025	Includes Rude pool, one well.
101			1	27,463	27,463	38	4,076	
102			14	1,433	1,433	38	7,688	
103		Abandoned March 1931			1,640			
104	1	0	2	25,005	25,005	26	1,303	

A tabulation of the 51 new discoveries in western Kansas (ranges west and the first three ranges east, herein used for convenience) made in 1935 is given in Table 3. Fifty-one new discoveries were made in 1935 compared to 36 discoveries made in 1934. Six new oil-producing horizons in old fields were found, and three new gas fields. New oil-producing areas as a result of wildcatting numbered 42.

The most outstanding success in drilling all wildcat and semi-wildcat wells with or without geological information was in Russell County, where of 60 wells started (½ mile or farther from production) 50 per cent, or 30 wells, were productive. These wells did not all open new pools, inasmuch as about half of them are now considered to be either extensions of older pools or as likely to join up in forming four or five general producing areas. The average initial production of all completed oil wells in Russell County was 588 bbl. per day.

Geological exploration methods aiding in the discovery of the new fields of 1935 are shown in Table 3.

TABLE 1.—(*Continued*)

Line No.	Field	Location, Survey, Township, Range	Producing Horizon	Date of Discovery	Average Depth, Ft.
	Sedgwick County				
105	Bentley	19–25–1W.	K.C. L	March 1934	2,911
106	Cheney	8–27–4W.	Viola L	Oct. 1935	4,023
107	Corn	2–27–1W.	Viola L	Oct. 1929	3,389
108	Cross	26–25–1W.	K.C. L	March 1929	2,690
109	Eastborough	19–27–2E. et al.	"Chat," Misener and Viola L	Aug. 1929	2,927 to 3,235
110	Goodrich	16–25–1E. et al.	K.C. L, Mis L, Hunton L	Dec. 1928	2,616 to 3,350
111	Greenwich	14–26–2E. et al.	"Chat," Viola L, Wilcox sand	Apr. 1929	2,850 to 3,327
112	Kechi	6–26–2E.	Burgess sand (Pen)	May 1929	3,005
113	Robbins	20–28–1E. et al.	"Chat"	April 1929	3,090
114	Schulte	6–28–1W.	Simpson	March 1934	3,650
115	Valley Center	1–26–1W. et al.	K.C. L, and Viola L	Aug. 1928	2,600 to 3,375
	Stafford County				
116	Gates	27–21–13W.	"Siliceous"	May 1933	3,705
117	Neola	15–25–11W.	Viola L	March 1934	
118	Richardson	31–22–11W. et al.	"Siliceous"	Sept. 1930	3,545
119	Riley	19–22–11W. et al.	"Siliceous"	July 1935	3,606
120	St. John	23–24–13W.	Oswald	May 1935	3,625
	Sumner County				
121	Caldwell	17–35–3W.	Wilcox sand	April 1929	4,778
122	Churchill	25–31–2E. et al.	Stalnaker sand and K.C. L et al.	July 1926	1,820
123	Douglas	23–34–2W.	Wilcox sand	July 1927	4,492
124	Latta	9–30–2W.	K.C. L	June 1927	3,040
125	Oxford	14 and 17 and 23 32–2E.	Stalnaker et al.	June 1926	
126	Oxford (Layton)	14–32–2E.	Layton sand	Sept. 1935	2,400
127	Oxford (Sil.)	14 and 23–32–2E.	"Siliceous"	May 1935	2,890
128	Oxford (Twnst.)	14–32–2E.	"Siliceous"	Oct. 1935	2,948
129	Oxford (Wilcox)				
130	Wellington	33–31–1W. et al.	"Chat"	Dec. 1929	3,656
	Trego County				
131	Rega	20–13–21W	Cong. (Pen)?	May 1929	3,960
132	Wakeeney	14–11–23W. et al.	Oswald	Sept. 1934	3,627
	Totals				

Various forms of geology used in locating the successful wildcat wells, surface, subsurface, core drilling, seismograph and magnetometer work, or a combination of the above methods, accounted for 75 per cent or better of the new producing areas discovered, and wildcatting on no geology the remainder.

Throughout 1935 there was an average of 12 seismograph parties at work in western Kansas, giving a total of 144 crew months, which cost, at an average of $9,000 per month per party, approximately $1,300,000. In this year about 320 core holes were drilled at an approximate total cost of $140,000. A small amount of surface detail mapping was done throughout the year, practically all the mapable part of western Kansas considered as possibly productive having been mapped in detail prior to 1930.

Oil production in western Kansas in 1935 (ranges west and first three ranges east) from all fields is shown in Table 1. The amount of oil produced from each field in 1935 is shown so as to compare with the

TABLE 1.—(*Continued*)

Line Number	Number Wells Producing 12-31-34	1934 Production, Bbl.	Number Wells Producing 12-31-35	1935 Production, Bbl.	Total Production to 1-1-36	Average Gravity	Pool Potential Rev. as of 1-1-36	Remarks
105	1	3,048	1	2,057	5,105	34	15	
106			1	2,245	2,245	38	62	
107		Abandoned March 1931			25,145			
108	3	9,564	3	12,600	34,537	35	35	
109	49	487,678	50	394,526	6,615,302	44	1,144	Potential shown for only 45 wells.
110	14	202,824	13	154,301	1,517,185	35 to 38	776	
111	38	896,933	41	749,742	7,534,500	39 to 42	4,658	All chat wells abandoned.
112	1	3,958	1	2,549	32,754	39	15	
113	26	355,870	52	1,013,238	1,943,007	42	5,211	
114	1	26,200	1	29,831	56,031	42	1,448?	Discovery well abandoned in June, 1935 after having produced 5088 bbl. in 1935. Pool revived in November, 1935 with No. 3 well, No. 2 D. & A.
115	71	741,610	73	571,756	18,163,849	43	2,011	
116	4	80,744	4	118,796	202,788	38	1,253	
117	1	5,680	Abandoned July 1934		5,680	40		
118	10	366,306	16	535,036	1,144,298	41	9,961	
119			2	22,070	22,070	41	1,954	
120			1	1,139	1,139	33	840	
121	3	71,856	3	56,080	1,048,529	47	386	
122	67	425,987	67	365,895	17,000,305	37	1,095	
123		Abandoned April 1931			15,180			
124	7	45,095	6	36,294	304,094	40	106	
125	67	360,935	55	313,024	10,071,699	37	741	
126			2	11,402	11,402		749	
127			25	920,488	920,488	38	274,108	
128			6	15,113	15,113	38	2,318	
129			1	900	900		917	It has since been determined that this well is producing from siliceous limestone.
130	5	80,472	19	277,805	683,662	42	6,650	
131		Abandoned 1934			12,290	35		
132			3	0	0	39	1,735	No pipe line outlet during 1935.
	1,583	28,934,358	2,168	37,879,851	185,616,067		839,120	

1934 figure, and the total cumulative production figure to Jan. 1, 1936 is given.

The compilation of Table 1 was made from records of the State Corporation Commission, and production is reported on the basis of 97 per cent of tank table calculations. Because of several unknown factors,

TABLE 2.—*Summary of Western Kansas Development during* 1935
(Area in ranges west only)

County	Wells				Oil Wells		Gas Wells		New Pools
	Number	Oil	Gas	Dry	Total I.P.	Av. I.P. per Well, Bbl. per Day	Total I.P., Millions Cu. Ft.	Av. I.P. per Well, Millions Cu. Ft.	
Barber	5	0	2	3			4	2	1
Barton	36	21	0	15	15,660	746			5
Ellis	10	5	0	5	3,656	731			3
Ellsworth	94	73	2	19	94,799	1,298	4	2	1
Gove	1	0	0	1					0
Graham	1	0	0	1					0
Grant	1	0	1	0			10	10	1
Harper	1	0	0	1					0
Harvey	35	25	3	7	8,168	326	31	10	3
Haskell	1	0	1	0			2½	2½	1
Kingman	9	6	2	1	822	137	7	3	0
McPherson	98	71	3	24	16,982	239	26	8	2
Ness	2	0	0	2					0
Pratt	6	4	1	1	995	249	16	16	1
Reno	141	114	12	15	139,759	1,225	156	13	3
Rice	204	172	4	28	143,615	834	48	12	6
Rooks	6	2	0	4	306	153			1
Rush	18	0	8	10			267	33	0
Russell	160	121	0	39	71,187	588			18
Saline	1	0	0	1					0
Scott	3	2	0	1	1,172	586			0
Sedgwick	9	2	0	7	1,550	775			1
Stafford	20	10	0	10	8,472	847			2
Sumner	18	15	0	3	6,463	431			3
Trego	4	2	0	2	529	264			0
Totals	883	645	38	200	514,135	797	553	14	52

	Per Cent		Per Cent
Percentage of dry holes drilled	22.7	Percentage of producers that are oil wells	94.1
Percentage of producers drilled	77.3	Percentage of producers that are gas wells	5.9
	100.0		100.0

TABLE 3.—*New Discoveries in Kansas*, 1935
(In ranges west and first 3 ranges east only)
Fields arranged alphabetically by counties

Field	Location Discovery Well	County	Discovery Date, 1935	Discovered by	Daily Potential of Discovery Well	Depth, Ft.	Gravity Oil	Producing Horizon		Geologic Work Aiding Discovery
								Name	Age	
1 Albert	30–18S.–15W.	Barton	1–23	Harris & Haun	320 bbl.	3613	38°	Basal sand	Cambrian?	Subsurface
2 Eberhart	14–19S.–11W	Barton	5–16	Downing et al	163 bbl.	3360	38°	"Siliceous"	Cam-Ord	Wildcat
3 Lanterman	15–19S.–11W.	Barton	1–22	Downing & Murfin	200 bbl.	3335	38°	"Siliceous"	Cam-Ord	Wildcat
4 Feist	29–18S.–11W.	Barton	11– 7	Torrey & Fiester	435 bbl.	3433	37°	"Siliceous"	Cam-Ord	Seismograph
5 Peter	24–20S.–11W.	Barton	9–21	Lario & Elwell	1368 bbl.	3291	43°	"Siliceous"	Cam-Ord	Subsurface and magnetometer
6 Wethered	28–31S.– 3E.	Cowley	7– 5	Frost & Study	606 bbl.	3406	35°	"Siliceous"	Cam-Ord	Core drilling and subsurface
7 Bemis[a]	16–11S.–17W.	Ellis	10–23	Roark et al.	540 bbl.	3040	29°	Topeka lime	Pen	Surface and subsurface
8 Ruder[a]	17–15S.–18W.	Ellis	9– 4	Palmer & Storm King	818 bbl.	3440	35°	Oswald lime	Pen	Wildcat
9 Victoria	3–14S.–17W.	Ellis	12–23	Twin Drlg. Co.	928 bbl.	3304	36°	Oswald lime	Pen	Core drilling
10 South Lorraine	26–17S.– 9W.	Ellsworth	4–17	Carter et al.	1140 bbl.	3179	46°	"Siliceous"	Cam-Ord	Seismograph and subsurface
11 Hickok	10–29S.–36W.	Grant	12–14	Piney O. & G. Co.	10 Million Gas	2740	Gas well	Sumner-Chase	Per	Subsurface
12 Hollow	7–22S.– 3W.	Harvey	10–9	Empire	100 bbl.	3607		"Siliceous"	Cam-Ord	[h]
13 Schowalter	6–22S.– 1W.	Harvey	2–19	Prunty	147 bbl.	3320	35°	Hunton L	Sil-Dev	Core drilling
14 Sperling	23–22S.– 2W.	Harvey	2– 6	Imo O. & G. Co.	1624 bbl.	3290	35°	Hunton L	Sil-Dev	Subsurface
15 Elliott	30–29S.–33W.	Haskell	12–30	Helmerich & Payne	2½ Million Gas	2747	Gas well	Sumner-Chase	Per	Subsurface
16 Wenger[b]	2–20S.– 1W.	McPherson	4– 7	Shell	265 bbl.	3364	26°	Viola L	Ord	Core drilling
17 Chindberg	13–19S.–3W.	McPherson	3–21	T. C. Johnson	227 bbl.	2363	37°	Lansing L	Pen	[i]
18 Cairo	7–28S.–11W.	Pratt	12–10	Skelly Oil Co.	16 Million Gas	4245	Gas well	Viola L	Ord	Core drilling[i]
19 Haven	30–24S.– 4W.	Reno	8–22	Haynes et al.	408 bbl.	3400	40°	Mis chat	Mis	Core drilling and subsurface
20 Lerado	11–26S.– 9W.	Reno	10–23	Shell	878 bbl.[g]	4156	42°	Viola L	Ord	Core drilling and subsurface
21 Yoder	34–24S.– 5W.	Reno	10–23	McPherson Drlg. Co.	176 bbl.	3501	36°	Mis chat	Mis	Core drilling and subsurface
22 Galt	8–18S.– 7W.	Rice	9–25	Continental	387 bbl.	3233	37°	"Siliceous"	Cam-Ord	Core drilling and subsurface
23 Gouldner	16–18S.– 9W.	Rice	6– 9	Vickers et al.	924 bbl.	3229	45°	"Siliceous"	Cam-Ord	Seismograph and subsurface
24 Keesling	10–20S.– 9W.	Rice	4–17	Gypsy Oil Co.	238 bbl.	3265	42°	"Siliceous"	Cam-Ord	Core drilling
25 Rickard	22–18S.– 9W.	Rice	9– 9	Aylward et al.	201 bbl.	3365	35°	Simpson	Ord	Subsurface
26 Stumps	4–18S.–10W.	Rice	3–27	Slick et al.	546 bbl.	3267	43°	"Siliceous"	Cam-Ord	Core-drilling
27 Wenke	7–20S.–10W.	Rice	2–27	Twin Drlg. Co.	182 bbl.	3374	45°	"Siliceous"	Cam-Ord	Subsurface
28 Zurich	26–10S.–19W.	Rooks	9– 2	Tree & Findiess	474 bbl.	3349	35°	Oswald	Pen	Surface and core drilling

TABLE 3.—(*Continued*)

	Field	Location Discovery Well	County	Discovery Date, 1935	Discovered by	Daily Potential of Discovery Well, Bbl.	Depth, Ft.	Gravity Oil	Producing Horizon Name	Producing Horizon Age	Geologic Work Aiding Discovery
29	Atherton[c]	30–13S.–14W.	Russell	7–18	McMorrow-Spencer	560	3290	31°	"Siliceous"	Cam-Ord	Surface
30	Berrick	6–15S.–13W.	Russell	12– 4	Coralena	130	2925	39°	Oswald	Pen	Subsurface
31	Big Creek[c]	36–14S.–15W.	Russell	6–13	Wakefield et al.	178	3176	35°	"Siliceous"	Cam-Ord	Subsurface
32	Bunker Hill	31–13S.–12W.	Russell	9–10	Roth & Faurot	274	3002	39°	Oswald	Pen	Wildcat
33	Cook[d]	26–13S.–15W.	Russell	6–19	Hartman-Blair	130	3331	26°	"Siliceous"	Cam-Ord	Subsurface
34	Cram	11–14S.–15W.	Russell	7–31	Shaffer	35	3130		Oswald	Pen	Subsurface
35	Donovan	10–15S.–15W.	Russell	2–15	Wolf Creek	233	3199	41°	Oswald	Pen	Wildcat
36	Dubuque	34–15S.–12W.	Russell	9– 1	Brouk et al.	456	3278	40°	"Siliceous"	Cam-Ord	Surface
37	Eichman	34–15S.–13W.	Russell	4–13	Hershey et al.	436	3326	36°	"Siliceous"	Cam-Ord	Surface
38	East Gorham (deep)	10–14S.–15W.	Russell	10–22	Wolf Creek	60	3192	34°	Basal sand	Cambrian?	Subsurface
39	East Gorham (Oswald)	10–14S.–15W.	Russell	9–25	Bridgeport	193	3105	38°	Oswald	Pen	Subsurface
40	Gurney	23–14S.–14W	Russell	9–21	Hartman-Blair	359	3006	38°	Oswald	Pen	Subsurface
41	Hall	30–14S.–13W.	Russell	1–11	J. J. Hall	594	3154	36°	Basal sand	Cambrian?	[h]
42	Karst[e]	27–15S.–14W.	Russell	9–30	Nassau Pet.	287	3319	38°	"Siliceous"	Cam-Ord	Surface and core drilling
43	Millburger[c]	7–14S.–14W.	Russell	4–29	Kirk-Jones	187	3315	35°	"Siliceous"	Cam-Ord	Subsurface
44	Sullivan (deep)[c]	35–13S.–15W.	Russell	7– 4	Hartman-Blair	426	3316	37°	"Siliceous"	Cam-Ord	Subsurface
45	Sullivan (Oswald)	2–14S.–15W.	Russell	2– 8	Hartman-Blair	220	3076	38°	Oswald	Pen	Subsurface
46	Cheney	8–27S.– 4W.	Sedgwick	9–21	Derby & Penn-West	102	4023	38°	Viola L	Ord	Seismograph and subsurface
47	Riley[f]	19–22S.–11W.	Stafford	6– 9	C. B. Davis	185	3593	41°	"Siliceous"	Cam-Ord	Subsurface
48	St. John	23–24S.–13W.	Stafford	5–15	Lario & Elwell	840	3628	33°	Oswald	Pen	Seismograph
49	Churchill (Kansas City)	25–31S.– 2E.	Sumner	12–18	Derby Oil	798	2335	36°	Kansas City Ls	Pen	[h]
50	Oxford (Layton Sd)	23–32S.- 2E.	Sumner	9–17	Lario-Barnsdall	730	2409	38°	Layton sand	Pen	[h]
51	Oxford (deep)	23–32S.– 2E.	Sumner	5– 8	Lario-Barnsdall	320	2899	38°	"Siliceous"	Cam-Ord	[h]

[a] Subsequently "Siliceous" production was discovered in an offset well, making two pay horizons in this pool.
[b] Well abandoned Aug. 1935, after testing "Siliceous."
[c] Subsequently Oswald lime production was discovered in an offset well, making two pay horizons in this pool.
[d] Lost hole after testing, so abandoned account mechanical trouble.
[e] A well with I.P. 4076 bbl. was found in this field in the Topeka Ls at T.D. 2799 on 5–1–35.
[f] Subsequently found to be a part of the Richardson pool, 1½ miles southwest.
[g] On a re-test after the bailer was fished out of the hole, this well tested for approx. 11,800 bbl. per day on Apr. 6, 1936.
[h] New producing horizon in an old field.
[i] Well plugged back to producing formation after being a failure in the "Siliceous."

chiefly that the limits of most of the oil pools in western Kansas have not been sufficiently defined, it is difficult to arrive at a satisfactory basis for computing a recovery figure on a per-acre, or any other, unit. Therefore, recovery figures for an arbitrary unit other than a field have been intentionally omitted.

Acid treatment continues to be more and more important, as the percentage of all new oil production that comes from limestone and dolomites in Kansas is increasing, compared to new production from sand reservoirs.

Since the average depth of all the successful wildcat wells drilled in Kansas in 1935 was 3225 ft., and of the dry holes 3475 ft., and there are still large untested areas in western Kansas, that region seems destined to see continued rapid exploration in 1936.

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Oil and Gas Development in Kentucky

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(New York Meeting, February, 1936)

The price of crude oil in Kentucky did not change very much during 1935 until the latter part of the year, but more stabilized conditions and an increase in consumption of natural gas made the year a more profitable one than the year 1934. The production of crude oil in 1935 amounted to 5,175,054 bbl. as compared to 4,814,904 bbl. in 1934. This increase was due to two developments: (1) the application of new recovery methods to old fields, which, although in operation in the state for several years, had never before reached a point where the production obtained, while highly satisfactory where applied, was sufficient to influence the totals in the production figures; (2) the development of the Fordsville area in Ohio County, where shallow depths enabled the operators to complete the development of a large number of wells with a good flush production probably accounted for most of the increase. A map showing the location of oil and gas pools in Kentucky was published last year.[1]

The fields of eastern Kentucky, producing from the Weir sand of the Waverly group of the Lower Mississippian series, in Johnson, Magoffin, Lawrence and Elliott counties, produced 826,001 bbl. of oil in 1935 as compared with 902,247 bbl. in the previous year.

No new wells were drilled in this area during the year, except those for use as intake wells in repressuring. What has been done in the few small areas within these fields in the way of repressuring has produced results sufficient to a great extent to offset the natural decline of all the field. It is probable the drilling of new wells and construction of new plants will be such as to cause these fields to produce more in 1936 than was produced in the past year. This is based on the fact that the sand is highly favorable for repressuring and the results obtained show from 300 to 500 per cent increase in production.

From the "Corniferous" pools, where production is from the Corniferous limestone of Devonian age, in Lee, Powell, Estill, Wolfe, Morgan and

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[1] C. D. Hunter and I. B. Browning: *Trans.* A.I.M.E. (1935) **114**, 309.

TABLE 1.—*Oil and Gas Production in Kentucky*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Oil and Gas[a]	Gas	Total	Total Oil Production, Bbl.: To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
1	Big Sinking, *Lee, Estill, Powell, Wolfe*	18	14,047			14,047	35,96*x,xxx*	642,259	64*x,xxx*[13]	1,7*xx*
2	Ida May, *Lee*	11	377			377	522,*xxx*	10,950	59,*xxx*[13]	16*x*
3	Pebworth, *Owsley*	12	60			60	66,340	1,633	2,896	
4	Ross Creek, *Estill*	18	468			468	748,616	10,510	20,733[14]	5*x*
5	Goocey, *Lee*	15					74,*xxx*	1,505	1,*xxx*[13]	
6	Trabue, *Lee*	6					87,*xxx*	11,600	10,*xxx*[13]	3*x*
7	Ashley, *Powell*	18	1,091			1,091	2,888,*xxx*	57,508	5*x,xxx*[13]	15*x*
8	Irvine, *Estill*	20	4,7*xx*			4,7*xx*	1,7*xx,xxx*	159,301	15*x,xxx*[13]	4*xx*
9	Wagesville, *Estill*	18	400			400	385,366	5,572	7,766	21.3
10	Campton and Stillwater, *Wolfe*	23	1,447			1,447	635,570	4,435	5,803	16
11	Buffalo Creek oil pool, *Owsley*	13	12			12	22,500	2,000	2,500	16
12	Island Creek, *Owsley*	10		20		20	9,899	0	0	0
13	Olympia, *Bath*	18[1]								
14	Menifee oil pool, *Menifee*	16[2]					231,835			
15	Ragland oil pool, *Bath and Rowan*	35[3]					258,930			
16	Cannel City, *Morgan*	23	600			600	377,151	1,962	1,011	3
17	Oil Springs, *Johnson and Magoffin*	16	6,100			6,100	8,594,443	220,088	217,639	55*x*
18	Burning Fork, *Magoffin*	13	918			918	1,593,743	74,128	63,933	17*x*
19	Blaine, *Lawrence and Johnson*	17	6,820			6,820	14,110,298	521,666	498,301	1,36*x*
20	Elna, *Johnson*	15					1,468,986	48,841	42,900	115
21	Louisa pool, *Lawrence*	23	1,*xxx*		600	1,*xxx*	1,459,994	40,528	38,438	106
22	Ambrose-Weller Pool, *Ohio*	10	600			600	3,229,500	120,000	109,500	300
23	Isonville, *Elliott*	19	100	46	2,000	2,146	78,584	3,378	3,227	9
24	Beaver Creek, *Floyd and Knott*	20	140			140	142,*xxx*	4,600	2,*xxx*[15]	1*x*
25	McKinney, *Lincoln*	16					4,502	0	0	0
26	Wayne County, *Wayne and McCreary*	38	8,544			8,544	4,326,613[7]	36,335	32,854	91
27	Logsdon Valley, Le Grande Bonnieville, *Hart*	2 and 3[4]	2,9*xx*		3,0*xx*	5,9*xx*	5,620,581[8]	514,000	279,074	764
28	Livermore, *McLean*	4 Mo.	150			150	23,171			
29	Barrett Hill, *McLean*	6	250			250	706,294			291
30	Owensboro, *Davies, Ohio, McLean, Hancock, Breckenridge*	17	10,800			10,800	23,738,196	2,073,036	3,953,037	10,460

[a] Footnotes to column headings and explanation of symbols are given on page 215.
[1] Depleted, abandoned since 1920.
[2] Depleted, abandoned 1930.
[3] Depleted, abandoned 1931
[4] Bonnieville Pool 3 years, Le Grande and Logsdon Valley, 6 years.
[7] Production from 1910 inclusive to end of 1935.
[8] The three pools put together as production cannot be separated.
[13] In the counties of Lee, Powell, Estill, and Wolfe, Kentucky, in which the Corniferous Devonian oil pools of Big Sinking, Ida May, Ross Creek, Goosey, Trabue, Ashley, Irvine, Wagesvile, and Campton Stillwater are located, in 1935 exact oil runs are available by county only. To obtain such runs for each pool is nearly impossible. During 1934 this separation of runs by pool required nearly two months of one man's time. During 1935 the four above-mentioned counties in which these pools are located produced 910,235 bbl. of oil as compared to 916,808 bbl. during 1934. Big Sinking Pool, located in all four counties, produced 70 per cent of the total.

	1934, Bbl.	1935, Bbl.
Lee	631,470	610,968
Estill	170,106	180,298
Powell	93,496	98,968
Wolfe	21,736	19,999

[14] Increase in production is due to cleaning out old wells with muriatic acid and reconditioning.
[15] Less than 0.5 per cent of wells drilled in the Floyd and Knott gas fields produce oil in commercial quantities, and as the only market is by railroad shipment or to a very small plant built during 1935, the exact production is very difficult to obtain.

Owsley counties in eastern Kentucky, 916,643 bbl. of oil were produced in 1935 as compared with 920,059 bbl. in 1934. During the year 52 oil wells, 31 dry holes and 11 intake pressure wells were completed. Repressuring in these fields has just started and the results are highly satisfactory.

TABLE 1.—(*Continued*)

	Average Oil Production, Bbl.			Total Gas Production Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1935		At End of 1935				
Line Number	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	2,6xx		0.6					2,404	20	2x[28]	0	2,404			52,19x
2	1,4xx		2x					97	15[29]	0	0	97			97
3	7.5		0.5					15				15			15
4	1,6xx		1.x					18x		0	0	18x			6x
5	0.x							13		0	0	13			11
6			2x					15			0	15			15
7	2,6xx		0.x					523			0	523			45x
8	2,5xx		0.x					1,1xx	[30]			1,0xx			1,0xx
9	963		0.9					100				100			3x
10	439		0.3					275				275			7x
11	1,891		4					7			3	4			4
12			0					6	0	0	2			0	
13								20							0
14								150							0
15				100								100			0
16	627		0.2					75		5		75			14
17	1,418		0.49					1,055				1,055			1,033
18	1,732		1.					159				159			159
19	2,069		1.2					1,118	0	0		1,118			1,118
20			0.5					250				250			230
21	1,xxx		0.1					286			12	286			234
22	5,400		1.5					190	0	0	0	190			190
23	787		0.4					39	[31]		3	24	4	8	31
24	1,4xx							39	4	1	8	39			.3
25								8	0	0[32]		4		4	0
26	543		0.1					1,451				1,451			8xx
27	1,9xx		1.9					1,2xx				1,0xx		2xx	9xx
28	160							5		1		5			4
29			5.4					55		2		55			53
30	2,190		3.2					3,200				3,200			3,200

[28] During 1935 twenty-one oil wells, six pressure wells, and fifteen dry holes were completed in the Big and Little Sinking oil pools of Lee and Estill Counties, Kentucky.

[29] During 1935 several pressure wells were drilled and the application of repressuring methods is responsible for a large percentage of production increase.

[30] During 1935 ten new oil wells, four pressure and two dry holes, were drilled in Estill County.

[31] Six to eight miles northwest of the Isonville 10 wells were drilled through the Weir sand during 1935. Three of these produce from 4 to 8 bbl. from the Weir, but to date no real pumping test has been made. The other seven were dry holes, or small gas wells.

[32] Field has been abandoned for several years.

With additional inside location development (many leases in these fields are very large, involving thousands of acres, and the inside areas were sparsely drilled), and the further development of the method of pressure application these fields will probably maintain or exceed their production during the coming year.

From the northwestern Kentucky, or Owensboro, field, embracing the numerous pools in Ohio, Hancock, Daviess, McLean, Henderson, Webster, and Muhlenburg counties, where production comes from Pennsylvanian and the Chester sands of the Mississippian series, 2,821,722 bbl. of

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1935				Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935					Character of Gas, Approx. Average during 1935	
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells: Flowing	Number of Wells: Pumping	Number of Wells: Air lift	Injection into Reservoir[d]	Initial	Average at End of 1934	Average at End of 1935	Gravity A.P.I. at 60° F.: Maximum	Gravity A.P.I. at 60° F.: Minimum	Gravity A.P.I. at 60° F.: Weighted Average	Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
1	700–1,200	650–1,150		2,19x		Air				42	37	40		P		
2	1,000–1,200	975–1,175		79										P		
3				15										P		
4	550– 900	520– 870		6x										P		
5				11												
6	940–1,140	900–1,100		15						42	40	41		P		
7	600–1,000	550– 950		4xx										P		
8	120–1,000	85– 960		1,0xx												
9	100– 400	75– 375		3x		Air								P		
10				7x												
11	1,125	1,110		4						42.8	40.8	41.8		P		
12												39		P		
13																
14	1,040–1,250	1,020–1,230														
15	650– 850	625– 825														
16	1,800–2,000	1,780–1,980		14												
17	900–1,260	860–1,220		1,033		Air 10	180	300	300	38	34	36.5		P		
18	1,080–1,400	1,040–1,360		159						38	36	36.5		P		
19	760–1,060	700–1,000		1,118			550	y	360	38	34	36.5		P		
20	640–1,100	600–1,060		230						38	34	36.5		P		
21	1,600–1,900	1,575–1,875		234						40	37	38.5		P		
22	725	650– 700		190						36.2		36.2				
23	875–1,500	825–1,350		23									0.17	P		
24	1,000–1,500	950–1,475	2	1										P		
25	121– 360	101– 390														
26	400– 700	385– 680		8xx												
27	700– 850	780–1,300		9xx										P		
28	1,250	1,225	2	2						37	35	36				
29	1,250	800–1,200		53			320		80	37	34	35.5				
30	600–1,300									35						

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/ or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935		Reference to Text[k]
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole in Feet	
1	Cornif.	Dev	LS	Por	30	MC	3xx[28]	Tren	2,xxx	
2	Cornif.	Dev	LS	Por	20±	MC	4x	Dev		
3	Cornif.	Dev	LS	Por	20±	MC	1x	Dev		
4	Cornif.	Dev	LS	Por	20±	T	3x	Ord		
5	Cornif.	Dev	LS	Por	2±		5x	Dev		
6	Cornif.	Dev	LS	Por	20± [43]	MC				
7	Cornif.	Dev	LS	Por	40±	AF				
8	Cornif.	Dev	LS	Por	40±	AF	1xx	Ord		
9	Cornif.	Dev	LS	Por	25±	AF	7x	Ord		
10	Cornif.	Dev	LS	Por	25±	AD	8x	Dev	2,190	
11	Big Lime	Mis	LS	Por	15	A	3	Dev	1,962	54
12	Big Lime	Mis	L	Cav	10–40	MC	10	Dev		
13	Sil.		L	Cav	10±	MC	7x	Ord		
14	Cornif.	Dev	LS	Por	20±	MC	4x	Ord		
15	Cornif.	Dev	LS	Por	25±	SC	1xx	Ord		
16	Cornif.	Dev	L	Por	20±	AF	2x	Dev		
17	Weir	Mis	S	Por	35	DA	9x	Ord	3,815	
18	Weir	Mis	S	Por	30	D	4x	Ord	3,900	
19	Weir	Mis	Sand	Por	60	D	1xx	Sil		
20	Weir-Berea	Mis	S	Por	30	DFAS	15x	Dev		
21	Berea	Mis	S	Por	20±	S	2x	Ord	4,975	55
22	Jett sand	Mis	S	Por 20%	12–75	AN[44]	56	Tren	4,020	56
23	Weir	Mis Dev	S, H, LS	Por	40± 20± 350±	A	8	Dev	1,780	
24	Maxon, Big Lime and Big Injun[45]	Mis	S, LS	Por Cav	15±	ML MC T[46]	3x	Ord	3,706	
25	Cornif.	Dev	LS	Por	18±	MC	4	Ord	855	57
26	Beaver	Mis	LS	Por	12	S	1xx	Ord	1,921	
27	Blue sand	Sil	L	Cav	15±	T MC A	2xx	Sil		
28	Bethel sand	Mis	S	Por		DF	7	Dev	3,350	
29	Jett, Jackson, Barlowe and Bethel	Mis	LS	Por 15%	30	AF	14	Dev	3,250	
30	Fugua stray, Pottsville, Jett, Barlowe, Jones	Pen Mis	S	Por 18–20%	2–75	AN A T D	1,1xx	Ord		

[43] In some of the Lee County oil pools as many as three different pays are encountered in the Corniferous. Pays vary in percentage of lime and silica content.

[44] Sand and depositional conditions control production and not structures.

[45] Oil when encountered in this field is from either sand pays in the Maxon and Big Injun sands, or crevice in the Big Lime horizons. Production is seldom continuous and only in two instances have offset wells of less than 600 ft. to oil producers encountered the same pays.

[46] Depositional conditions of the oil-productive horizons are more responsible for accumulation than is structure.

[54] Ky. Geol. Survey: New Oil Pools in Kentucky.

[55] Owens Bottling Co.

[56] Univ. of Kentucky *Bull.* 3.

[57] Jillson: Ky. Geol. Survey (1922) [6].

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
31	Henderson, *Henderson*...	5	218			218	414,807	59,321	61,590	156
32	Muhlenberg, *Muhlenberg*	6					223,138	35,858	26,166	62
33	Bowling Green, *Allen, Warren and Simpson*..	17	10,356			10,356	11,848,685	233,738	216,234	583
34	Barren, *Barren*..........	17	3,667			3,667	2,354,811	46,705	49,198	120
35	Floyd gas field, *Floyd*....	32	See Beaver Cr.		221,275	221,275				
36	Pike Co. gas field, *Pike*..	5[5]			54,200	54,200				
37	Martin, *Martin*.........	38	10		72,300	72,310				20
38	Knott gas field, *Knott*....	30	50	50	94,000	94,100				1,221
39	Boyd County and Ashland, *Boyd*...........	11			16,640	16,640				
40	Perry gas (Hazard), *Perry*	5			1,200	1,200				
41	Oneida—Burning Springs, *Clay*.................	10			7,000	7,000				
42	Burning Springs gas, *Clay*	36								
43	Indian Creek gas, *Knox*..	6	0	0	1,200	1,200				
44	Artemus-Himyar, gas, *Knox*................	5	0	0	5,000	5,000	0	0	0	0
45	Red Bird gas field, *Bell*..	5			600	600				
46	Williamsburg oil and gas pool, *Whitley*.........	33		700		700	4,000[9]			

[5] Not until 1929–30 was gas commercially developed in Pike County. Until then some 30 wildcat shallow tests for oil had been drilled over the county.

[9] Oil production is from the Pennsylvanian salt sands and in all this small pool never exceeded 175 bbl. per month. From August, 1919, to Sept. 1922, 3278 bbl. of oil was run. Several of these oil wells were deepened to Mississippian Big Lime where large open flows of gas were encountered. Some wells are reported as large as 3,500,000 cu. ft. open flow and original pressures of 240 lb. This production is utilized domestically in the town of Williamsburg.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production in Millions of Cubic Feet				Number of Oil and/or Gas Wells							
									During 1935		At End of 1935				
	Per Acre to End of 1935[5]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[e]	Producing Gas Only	Total Producing
31	1,901		2.6					63				63			63
32			3					20				20			20
33	1,144		0.3					2,026				2,0xx			1,9xx
34	642		0.2								791				
35				y	y	y	y	1,157[33]	41	1x	[34]			1,1xx	1,1xx
36				y	y	y	y	155			2x			155	1xx
37				y[16]	y	y	y	213	16		1x	1		212	213
38				y	y	y	y	160	20	0		1		156	157
39				y[17]	y	y		216	0	3x		2		214	1xx
40				y	y[18]	y	y	6		2	2			6	2
41				y	y	y		24			20			4	4
42				y	y[19]	y	y	5						5	
43				y	y	y		7	1	0					7
44	0			y[20]	y	y		19	1	0	12			19	7
45				[21]				3			3			3	0
46								30				25	0	5	5

[16] Martin County, one of the oldest gas producers in the state, still remains second only to Floyd County in importance. Knott County, Ky., is close to second and may take precedence over Martin County during 1936.

[17] Although 70 per cent of the gas development was after 1928, W. R. Jillson has fully outlined this development to 1926 in his Kentucky Geological Survey, Ser. VI, New Oil Pools of Kentucky.

[18] Production furnishes town of Hazard domestic.

[19] Gas production from this field is utilized only locally for domestic purposes.

[20] During 1931–32 eighteen gas wells were drilled in the Artemus-Himyar field of Knox County, Ky., developing 15,000,000 cu. ft. of open flow.

[21] No market for developed gas.

[33] Does not include oil wells. See Beaver Creek.

[34] Less than 15 gas wells are not connected to pipe line. The average well is shut in four months of the year. Only during December, January and February are over 90 per cent of the wells on line.

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935: Number of Wells: Flowing	Number of Wells: Pumping	Number of Wells: Air lift	Injection into Reservoir[d]	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1934	Average at End of 1935	Character of Oil, Approx. Average during 1935: Gravity A.P.I. at 60° F.: Maximum	Gravity: Minimum	Gravity: Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
31				63												
32	1,250–1,700			20												
33	270– 700	265– 785		1,9*xx*												
34																
35	1,100–3,500[16]	900–3,100[16]													1,150	
36	[36]														1,150	
37	1,100–3,250	700–3,000	1									34			1,150	
38	1,300–3,500	1,250–3,000	1												1,150	
39	2,200±	1,650±					*y*	*y*	*y*							
40	2,700–3,300	2,200–2,900														
41	1,550–1,700	1,525–1,675					305									
42 43	1,550	1,500					See Pet. Expl.			See Pet. Expl.						
44	1,110±–2,100±[37]	1,080±–2,000±[37]					310	310	310[41]						1,180	0
45	3,500±	3,400±														
46	Oil 900± Gas 1,750±	860± 1,700±					240							P		

[35] Increase in depth due to development of Lower Devonian limestone.

[36] Gas-producing horizons in Pike County are from 15 to 20 per cent deeper than in Floyd. The dip from Floyd County S.E. to Pike County is approximately 30 ft. per mile.

[37] Producing horizons in this pool are Maxon from 1080 to 1110±, Brown shale from 1780 to 1950±, and Corniferous lime from 1960 to 2100±.

[41] Of intensive interest in this field is the fact that the rock pressures of all sands, both shallow and deep, are around 300 lb. The only explanation the author can reasonably assume is the fact that the Artemus anticline south of the gas field is traversed by a fault. This, with other disturbances caused by the Pine Mountain overthrust fault, 15 miles to the southeast, has permitted the pressures of the various horizons to equalize.

TABLE 1.—(*Continued*)

Line Number	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Depth of Hole in Feet	Reference to Text[k]
31	Triplett, Jones	Pen Mis	S	Por	30±	DA	6*x*	Dev		
32	Big Lime	Mis	LS	Por	20±	D	2*x*	Dev		
33	Shallow sand Cornif. Deep sand	Mis Dev	LS	Por	15±	DT A MC	1,*xxx*	Ord		
34	Second sand, Trenton, Amber oil sand Cornif.	Mis Dev Sil Ord	LS	Por	10±	MC T D N	1,*xxx*	Ord		
35	Big Injun, Salt sand, Maxon, B. Lime, Dev shale and Cornif. lime	Pen Mis Dev	S, L, LS, H	Por Cav	15–550	AD MC T NS	95	Sil	3,643	
36	Dev. shale, Salt sand, Maxon, Big Lime, Big Injun	Pen Mis Dev	S, L, H	Por Cav	10–800	A AM H MC D T S	36	Dev	4,181	
37	Salt sand, Maxon Big Lime, Big Injun, Dev. shale	Pen Mis, Dev	S, L, H	Por Cav	10–600	A AF D T MC S	33	Dev		
38	Brown shale, Big Injun salt sand, Maxon and Big Lime	Pen, Mis, Dev	S, L, H	Por Cav	20–500	A AM H MC D T S	19	Ord	3,706	
39	Corniferous, Salt sand, —Maxon, Black shale[47]	Pen, Mis, Dev	S, H, SL	Por	50–400–150	T	29	Ord	4,669	58
40	Salt sand, Big Lime, Brown shale	Pen, Mis, Dev	S, L, H	Por Cav	50± 500±	MC	11	Dev	3,673	
41	Corniferous	Dev	LS	Por	20±	A MC	15	Dev	2,284	
42	Corniferous	Dev	LS	Por	25±		1*x*	Dev		
43	Big Lime	Mis	L	Cav[48]	20	T	1	Mis	1,552	
44	Maxon, Brown shale, Corniferous	Mis, Dev	S, H, LS	Por	30± 175± 100±	A AF D	2	Dev	2,225	
45	Big Lime, Brown shale, Corniferous	Mis, Dev	L, H	Cav Por	100± 175± 50±	MC[48a]	2	Dev	3,725	
46	Salt sand Big Lime	Pen, Mis	S, L	Por Cav	Oil 30± Gas 20±	A	1*x*	Ord	3,350	59

[47] In the Ashland gas field the Gordon sand appears in lenticular bodies producing wells of large open flow, but at no other place in Kentucky does this sand appear.

[48] Although five of the producing gas wells are on the Indian Creek dome, which has only a small closure, the authors are of the opinion that production is controlled entirely by accumulation in creviced limestone with no direct relation to structures.

[48a] Structures, especially minor structures, are of very little or no importance in Kentucky's gas development. Depositional conditions such as alterations from sands to shales, old sand shore limes, and leaching of limes are of far greater importance. In most cases production shows no relation whatsoever to minor folds.

[58] New Oil Pools in Kentucky. Ky. Geol. Survey (1926) [6].

[59] Jillson: New Oil Pools of Kentucky. Ky. Geol. Survey [6]

oil were produced during the year 1935 as compared to 1,977,957 in 1934. During the year the development in the Fordsville fields, consisting of four distinct areas or fields, was brought to completion. This accounts for most of the additional oil produced. The Jett (Tar Springs) sand, the producing sand in the fields, lies at a shallow depth, 300 to 400 ft., and development was rapid with the wells making an initial of about 150 bbl. per day. Approximately 200 oil wells were completed in the area during the year.

During the month of November a new pool was discovered just north of Livermore in McLean County. At the end of the year six wells had

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Area Proved, Acres: Oil and Gas[a]	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1935	Total Oil Production, Bbl.: During 1934	Total Oil Production, Bbl.: During 1935	Total Oil Production, Bbl.: Daily Average during Nov., 1935
47	Big Six gas, *Breathitt*	16			1,200	1,200				
48	Rothwell gas field, *Menifee*	34	0	0	15,360	15,360				
49	Powell gas, *Powell*	4								
50	Carlisle gas field, *Gallatin and Carroll*	4								
51	Swamp Branch gas field, *Johnson*	8	3	0	3,000	3,003	Not Marketed	0	0	
52	Flat Gap gas field, *Johnson*	16			10,880	10,880				
53	Win gas field, *Johnson*	18			1,980	1,980				
54	Cain, *Lawrence*	6	0	0	550	550	0	0	0	
55	Green-Taylor gas, *Green-Taylor*	16								
56	Cumberland—Clinton, *Cumberland, Clinton*	41					2,*xxx*,*xxx*[10] [11]		185	
57	Little Richland, *Knox*	33								
58	Ivyton, Licking and Mine Fork gas, *Magoffin*	16			6,840	6,840				
59	Needmore gas field, *Owsley*	15			6,400	6,400				
60	Morton's Gap, *Hopkins*	13	50			50	[12]		500	
61	Buford, *Ohio*	6	346			346	1,131,800	150,000	141,800	
62	Habit, *Daviess*	5	100			100	200,000		29,200	80
63	Lindsay Taylor pool, *Daviess*	6	15			15	22,577	1,200	1,277	3.5
64	Herbert, *Ohio and Hancock*	15	350			350	389,670	20,000	19,670	54
65	Red Hill pool, *Daviess*	8	400			400	388,000	24,000	60,000	161
66	North Triplett gas field, *Rowan*	31[6]			1,200	1,200				

[a] Not totaled because some small individual pools are included in County total.

[6] Some 8 or 10 wells were drilled in Rowan County following 1904, after the development of Ragland oil field in adjoining Bath County. Some of these wells produced gas from the Corniferous lime and two still produce gas for local use.

[10] Cumberland and Clinton counties have produced over two million barrels of oil, but as oil has been shipped by water, truck, pipe line and railroad for over 40 years, production figures are impossible. The old American well was drilled in Cumberland County over 90 years ago, and oil from same was used for medicinal purposes in this country and Europe.

[11] This is Kentucky's second oldest oil field. No production figures are available because oil was shipped by water or utilized locally.

[12] September to December, inclusive: 4,902 bbl. in 1923; 12,912 bbl. in 1924; 10,524 bbl. in 1925.

been completed with an average initial of 200 bbl. per day—some wells have an initial of 750 bbl. The Bethel sand, the lowest in the Chester group, is the producing formation and is found at a depth of 1350 to 1400 ft. The structural condition in the field is that of a lenticular body of sand on a plunging anticline in a horst between two faults with displacement of 500 ft. on the north side and less than 100 ft. on the south side. The faulting is part of that constituting the Rough Creek fault zone. The limits of the pool have not yet been defined and the present

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production in Millions of Cubic Feet				Number of Oil and/or Gas Wells							
									During 1935		At End of 1935				
	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[e]	Producing Gas Only	Total Producing
47				y[22]	y	y		10	[38]	10				10	0
48				y[23]				8x							0
49				[24]				2x	2					2x	
50														17	
51				y	y	y	y	22	0	0	22	2	1	19	19
52				y	y	y	y	2xx	0	0	1xx[39]				1xx
53				y[25]	y	y	y	28							
54				0	0	0	0	9	0	0	9		9		9
55				[26]				1xx						1xx	
56															
57															
58				y	y	y	y	104	0	2				104	8x
59							2,000	48						48	48
60								5				5			4
61	3,300		3.0					125	3	3	129				129
62	2,000							11	1	1	0	11		2	12
63	1,480		1.0					3				3			3
64	1,100		0.4					131	1	0	0	131			131
65	1,190	109	4.3					45	0	0		45			37
66				[27]				17	9	0	10			10	10

[22] During 1935 the 6-in. pipe line serving this field was removed, and the few wells that are not depleted are utilized only locally.
[23] Menifee gas field exhausted, now being used for gas storage.
[24] Gas production from this field is utilized domestically in the small town of Stanton and as fuel to pump oil wells in Lee County.
[25] This field is practically depleted.
[26] Gas from this field has been used for local domestic purposes and for the manufacturing of carbon black. All carbon manufacturing has been discontinued.
[27] Gas not being marketed, average well 187,000 cu. ft. This production will possibly find domestic market in town of Morehead 3 miles to the east, in which the Morehead State Teachers College is located.
[38] During 1935 one gas well was completed 2 miles north of Jackson county seat and 5 miles south of old Big Six gas field. Production was encountered in the Corniferous lime and will be piped to Jackson for domestic market.
[39] This Weir gas field is near depletion.

proven area covers approximately 400 acres. It is probable that the Barlowe sand will yield some large wells on the west side of the structure. A recent completion in this sand made 1,300,000 cu. ft. of gas and 20 bbl. of oil.

The discovery of the Livermore pool following that of the Barrett Hill pool, with very similar geological conditions, has stimulated interest to a high degree in the areas involved in the fault zone of the Rough Creek fault and to the south of that fault. Heretofore these have been avoided by the operators, partly because of the belief that production could not be found in so highly faulted an area and because of deeper and more expensive drilling costs. Production and acreage recovery in the Barrett Hill field and as indicated in the Livermore pool have been such as to counter-

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1935				Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935					Character of Gas, Approx. Average during 1935	
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells			Injection into Reservoir[d]	Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]	B.T.U. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
			Flowing	Pumping	Air lift			1934	1935	Maximum	Minimum	Weighted Average				
47	1,750–1,900	1,725–1,875														
48	550– 700	500– 650														
49																
50	240– 350	225– 335					160		20							
51	1,800	1,425														
52	780–1,200	740–1,160														
53	700–1,100 2,100–2,500	670–1,070 2,050–2,450											[42]			
54	1,670–1,760	1,650–1,740														
55	340– 700	370– 680														
56																
57	200– 500															
58	1,100–1,400	1,050[40]–1,350														
59	900–1,200	850–1,150					317								1,085	[50] 1 Qt.
60				4												
61	600	585		129						36		36				
62	930	910		10						35		55				
63	1,125	1,085		3												
64				131						35.8	33	34.4		P		
65					37							34				
66	350	335					45									

[40] Three different Weir oil and gas pays are encountered.
[42] Gas from the Corniferous in this field is so impregnated with SO_2 that it is noncommercial at this date.
[50] Gas from the Weir gas fields is higher in gasoline per 1000 cu. ft. than gas from any other horizon in eastern Kentucky.

act to a large degree this objection. It is probable that the coming year will see great activity in the fault area, which should uncover new profitable pools. Another interesting development in McLean County has been the discovery of oil in a Pennsylvanian sand which is found about 500 feet below No. 9 coal. This new pool is seven miles southwest of the Livermore pool. Production is found at a depth of 500 ft. The wells have an initial of from 20 to 150 bbl. The producing structure is a long sharply folded anticline which is probably

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935		Reference to Text[k]
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole in Feet	
47	Big Six	Sil	S	Por	25±	A	1x	Sil		
48	Corniferous / Ragland sand	Dev	LS	Por	40±	D	4x	Ord		
49	Corniferous	Dev	LS	Por	20±	MC	1x			
50	Trenton	Ord	LS	Por	15±	D	1x	Ord	967	
51	Maxon, Big Lime and shale	Mis, Dev	S, L, H	Por, Cav	40± 350±	Depositional	0	Dev		
52	Weir, Corniferous[49]	Mis, Dev	S, LS	Por	40±	D	2x	Ord	3,719	
53	Weir, Big Six	Mis, Sil	S, LS	Por	30±	A	8	Dev		
54	Corniferous	Dev	LS	Por	18	MC	7	Dev	1,983	
55		Ord	LS	Por	20±			Cam-Ord	1,934	
56	Sunnybrook—Trenton	Ord	S, LS	Por		AD				
57	Salt sand	Pen	S	Por	15±	A				
58	Weir, Black shale, Cornif, Salt sand, Maxon Big Lime and Injun	Pen / Mis / Dev	S, H, L	Por, Cav	40± 450±	DA / MC / TS	57	Ord	3,950	60
59	Corniferous	Dev	LS	Por	40±	MC	25	Dev		
60	Salt sand, Caseyville	Pen, Mis	S, L	Por	20± 6±	A F		Mis	2,132	
61	Pottsville	Pen	S	Por[51]	15	Channel	84	Mis	1,250	
62	Fugua, Stray sand	Mis	S	Por, 18–20%	20	A	10	Mis	1,350	56
63	Jones, Hardingsburg SS	Mis	S	Por	40	AF[52]	13	Mis	1,340	61
64	Jett and Barlowe	Mis	S, LS	Por[53]	5–50	TA	35	Mis	950	
65	Jett	Mis	S	18% Por	2–22	A N	19	Mis	1,020	
66	Cornif. lime	Dev	LS	Por	11	MC	7	Ord	1,501	62

49 The Corniferous in this field is impregnated with SO_2.
51 Owing to the high porosity of sand, this pool will probably show a recovery of 65 per cent. Estimated recovery 2,500,000 barrels.
52 The Jones sand of the Lindsay Taylor pool, although 40 ft. thick, carries oil only in the top 12 ft. The sand of the offset dry holes is too shaly to carry oil. Structure is not the important factor.
53 The Jett sand on one lease varies in thickness from 5 to 52 feet.
60 Kentucky West Virginia Gas Co.
61 Ky. Geol. Survey (1930) [5].
62 Ky. Geol. Survey (1922) [6].

faulted in the north side. The only deep well drilled in this structure yielded a 1,500,000 cubic foot wet gas well in the Jett (Tar Springs) sand. This well also showed for an eight-barrel well in the Bethel sand indicating the opening of another Bethel sand pool.

In the shallow areas of production in Hancock and Ohio counties, repressuring has been started by a number of operators and has been responsible for considerable additional production from those fields. The low cost of intake and new oil production wells makes this area highly favorable for this method, and with the results obtained to date it is probable that the next few years will see extensive application of the method in that section and maintain the production at its present levels or higher.

In the older oil-producing counties of Allen, Barren, McCreary, Metcalf, Simpson, Warren and Wayne, and the new area of Hart County, 590,461 bbl. of oil were produced in 1935. This compares with 831,003 bbl. in 1934. The difference is due almost wholly to the decline in the flush fields of Hart County, which were at their peak or just over in 1934. These pools were the LeGrande, Logsdon Valley and Bonnieville. The production is from the Louisville limestone just under the Devonian black shale. The formation is a honeycomb limestone and the wells had a high flush production but declined rather rapidly. Outside of Hart County probably few, if any, new oil wells were completed in these counties. On the contrary, many were abandoned, especially in Wayne County.

In the gas fields of Floyd, Martin, Knott, Pike and Magoffin counties of eastern Kentucky, 91 new gas wells were completed, also 4 wells producing oil, and only 3 dry holes. The production from over 1900 gas wells in these five counties is delivered by two 20-in., one 16-in, one 12-in., one 10-in., and one 8-in. pipe line to cities in Ohio, Washington, D.C., and other eastern cities, and to Louisville, Lexington, Frankfort, Winchester, Ashland, Covington, and other Kentucky towns for both industrial and domestic use. The drilling done was about what was considered as necessary to maintain present production figures. No new activity was noted or extensive efforts made to discover new producing areas.

In Western Kentucky, including all the counties of the "Owensboro field" named above, and in addition Hopkins, Mead, Breckenridge, Hardin, Hart, and Grayson counties, gas is marketed from 600 of the wells through pipe lines of the Louisville Gas and Electric Co. to Louisville, and those of the Kentucky Natural Gas Corporation to Owensboro, Bowling Green, Madisonville, Hopkinsville, Henderson and many other western Kentucky towns, and to Evansville, Terre Haute and many other smaller towns in Indiana. Kentucky still maintains its place as one of the leading producers of natural gas in the Appalachian Region.

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Oil and Gas Development in Louisiana

By B. C. Craft,* Baton Rouge, La.

(New York Meeting, February, 1936)

Oil and gas development in Louisiana during 1935 brought this state at the close of the year up to fourth place in the nation as a producing area.

A review of development in North Louisiana centers around Rodessa, the most important reserve discovered in this area in many years. While the producing limits have not been defined, this discovery is one of the major developments of the year. New gas fields were discovered in Lincoln, De Soto and Bossier parishes. The Lincoln Parish discovery, completed flowing a highly saturated gas from the Glen Rose, further indicates the importance of deep-seated prospects in the interior salt-dome area. Minor extensions were made at Sligo and Pine Island.

During the year, 126 oil wells and 103 gas wells were completed in North Louisiana as compared with 144 oil wells and 68 gas wells during 1934. The North Louisiana oil production was 9,617,405 bbl. as compared with 9,274,050 bbl. during 1934, an increase of 343,355 bbl., while the gas production increased 18 billion cu. ft. in 1935 over its 1934 figure. The Louisiana Department of Conservation gage of Nov. 1, 1935, shows an open-flow capacity of 4,563,725,000 cu. ft. per day from 941 wells in the Monroe field and 682,770,000 cu. ft. from 159 wells in the Richland field.

A great deal of leasing continues in North Louisiana as a result of the Lincoln Parish discovery and development in the Rodessa field, especially in Bossier, De Soto, Winn, Lincoln, Bienville, Webster, Ouachita and Richland parishes.

South Louisiana's position as an area of important reserves was further proved during the past year. Increased drilling resulted in the discovery of seven new fields: Lafitte, Garden Island Bay, Tepetate, Bunkie, St. Martinsville, Jeanerette and Big Lake. New sands or producing horizons proved productive in 15 of the proven fields.

The total oil production for South Louisiana during 1935 was 40,731,056 bbl. as compared with 23,255,437 bbl. during 1934. There were 222 oil and gas wells completed in South Louisiana during 1935 as compared with 214 oil wells during the previous period. Drilling during

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1936 will be divided between the new fields discovered this year, many of which have only one producing well, and several important geophysical prospects.

North Louisiana

Rodessa.—Presence of oil in commercial quantities in the Lower Glen Rose of the Trinity was proved in the Rodessa area, north of Shreveport,

TABLE 1.—*Oil and Gas Production in Louisiana*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
1	Caddo[1], *Caddo*	32	32,500	0	15,040	47,540	146,852,340	2,294,115	2,481,445	6,670
2	Red River, Bull Bayou, *DeSoto, Red River*	22	11,000	0	3,300	14,300	55,777,065	544,540	514,715	1,355
3	Lake Bisteneau, *Bienville*	20	0	0	600	600				
4	Elm Grove, *Caddo, Bossier*	20	320	0	14,600	14,920	3,048,105	135,120	145,555	390
5	Monroe, *Ouachita, Morehouse, Union*	20	0	0	123,340	123,340				
6	Bethany[2], Waskam, *Caddo*	20	0	0	1,800	1,800				
7	Homer, *Claiborne*	17	0	3,024	0	3,024	65,455,785	967,605	969,485	2,630
8	Haynesville, *Claiborne*	15	0	7,480	0	7,480	65,410,800	1,371,630	1,272,125	3,430
9	Shongaloo, *Webster*	15	70	0	5,680	5,750	95,920	7,485	6,890	
10	Bellevue, *Bossier*	15	1,360	0	160	1,520	9,351,725	63,825	212,215	535
11	Sligo, *Bossier*	14	0	0	4,400	4,400				
12	Spring Hill—Sarepta, *Bossier, Webster*	14	570	0	1,120	1,690	1,267,140	162,970	130,465	290
13	Cotton Valley, *Webster*	14	3,900	0	2,700	6,600	14,669,110	190,765	153,685	350
14	Carterville, *Bossier*	12	720	0	2,720	3,440	1,398,225	92,810	59,470	185
15	Urania, *Winn, Grant, LaSalle*	11	3,700	0	0	3,700	20,237,900	1,124,145	1,084,965	2,705
16	Richland, *Richland*	10	0	0	49,280	49,280				
17	Pleasant Hill, *Sabine, DeSoto*	9	800	0	0	800	1,379,635	75,535	64,360	175
18	Zwolle, *Sabine*	8	64,000[3]	0	0	64,000	12,504,050	1,678,710	626,080	1,370
19	Epps, *East and West Carroll*	8	0	0	1,200	1,200				
20	White Sulphur Springs, *LaSalle*	8	80	0	0	80	12,290	0	0	
21	Holly, *DeSoto*	6	80	0	0	80	805,745	65,385	57,480	155
22	Rodessa, *Caddo*	6	4,000	0	3,100	7,100	1,411,890		1,411,890	10,990
23	Sugar Creek, *Claiborne*	5	0	0	2,800	2,800				
24	Clayton, *Concordia*	5	0	0	60	60				
25	Converse, *Sabine*	4	1,600	0	0	1,600	1,072,510	554,410	425,580	1,325
26	Total, North Louisiana		124,700	10,504	231,660	366,864	400,750,235	9,274,050	9,617,405	32,555
27	Jennings, *Acadia*	35	235	0	0	235	51,497,262	451,991	668,054	1,829
28	Anse La Butte, *St. Martin*	34	25	0	0	25	801,910	11,850	17,798	43
29	Welsh, *Jefferson Davis*	33	50	0	0	50	596,473	9,831	15,638	33
30	Vinton, *Calcasieu*	26	265	0	0	265	41,419,960	1,141,041	912,959	2,028

[a] Footnotes to column headings and explanation of symbols are given on page 215.
[1] Includes the following districts: Cedar Grove, Shreveport, Jeems Bayou, Trees City, Monterey, Harts Ferry, Ferry Lake, Mooring Port, Gilliam, Pine Island, Vivian Dixie and Blanchard.
[2] Includes the part of each field in Louisiana and the Greenwood area.
[3] Scattered production over 64,000 acres.

when United Gas Public Service Company's I. L. Young No. 1, sec. 21, 23 N., 16 W. was compieted flowing 2400 bbl. of 43.5° A.P.I. oil per day and 1,000,000 cu. ft. of gas through a ¼-in. choke, with a tubing pressure of 910 lb. and casing pressure of 1820 lb. from a total depth of 6048 ft. There were three producing horizons in the higher part of the field which yielded a wet gas containing from 500 to 1000 gal. of gasoline per million cubic feet of gas. These zones are called the Hill, Gloyd and Dees.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1935		At End of 1935				
	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	4,518		6	133,463	1,401	1,947	7	3,810	65	5	10	1,088		39	1,127
2	5,070		7	61,229	1,447	1,385	5	1,246	8	1	6	183		35	218
3				2,012	0	0		10	0	0	0				
4	9,525		11	209,571	2,854	2,138	8	249	0	0	0	35		45	80
5				1,856,258	163,376	181,698	588	966	58	0	5			955	955
6				6,013	1,629	841	3	67	0	9	2			7	7
7	21,645		7	y	191[3a]	84	y	627	0	0	0		365		365
8	8,878		11	y	[4]	895	y	766	0	0	6		329		329
9	1,370			70,484	169	151	0.5	91	0	0	0	2		7	9
10	6,876		8	2,175	131	79	0.5	358	6	0	0	66		1	67
11				[5]	3,386	4,910	15	66	8	0	0			37	37
12	22,230		24	25,503	29[6]	35	0.2	43	0	0	0	12		1	13
13	3,761		5	71,291	2,167	1,768	5	278	0	0	19	56		33	89
14	1,942		4	16,955	0	0		133	0	0	6	51			51
15	5,470		14	5	0	0		449	6	0	3	203			203
16				421,839	32,373	21,450	71	284	0					157	157
17	1,724		5					57	0	4	3	35			35
18	1,954		17					310	3	59	0	81			81
19				923	142	173	2	5	0	0	0			4	4
20	153							12	0	0	0				
21	10,072		26		0	0		14	2	0	0	7			7
22	353		478	45,675	13,934	22,346	98	62	44	0	0	38		24	62
23				21,409	4,238	5,716	17	11	0	0	0			11	11
24				11	0	0		1	0	0	1				
25	670		19					124	19	20	5	68			68
26					227,467	245,616		10,039	219	–		1,923	694	1,356	3,975
27	219,137		44					519	4	0	0	44			44
28	32,076		14					35	1	0	1	4			4
29	11,929		2					67	1	0	0	17			17
30	156,301		25					438	0	0	0	82			82

[3a] Estimated.
[4] Included with Homer.
[5] Included with Elm Grove.
[6] Spring Hill gas production; Sarepta gas production included with Cotton Valley.

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935: Number of Wells: Flowing	Pumping	Gas-lift	Air-lift	Injection into Reservoir[d]	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of: 1934	1935	Character of Oil, Approx. Average during 1935: Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	2,067[7]	[8]		1,088			G	415–1,650	361[17]–250	3*xx*–2*xx*	25–46	14–26	38	0.5–0.35	A, P
2	823–2,648 3,577	787–2,600		183			G	350–975	295	2*xx*	41.5	40	41	0.25	P
3	2,018–2,553	1,993–2,544						800–1,056	0	0					
4	1,645[9]	1,621[9]		35				400–1,100	25–70–90	30–75–63	32	28	30	0.40	M
5	2,205	2,145						1,050	466	450					
6	1,823	1,718[10]						400–1,325	450[18]	310[18]					
7	1,345–2,065	1,280–2,040		365			G	*x*	0	0	38	35	36	0.80	P
8	2,805–4,844	2,790–4,559		329			G	*x*	12	12	35	32	33	0.40	P
9	2,680	2,665		2				1,050	40	40	30	28	29	0.35	M
10	370–1,035–1,815	360–1,010–1,790		66				175–750	250	2*xx*	20	19	19.2	0.80	A
11	[11]	[11]						375–1,825	0–1,840	[11]					
12	2,691–3,063–3,165	2,686–3,059–3,143		12				1,300	96	9*x*	28	25	26	0.32	M
13	2,547–4,652	2,532–4,350		56				1,080–1,750	225	160	30–52	29–48	31	0.25 0.09	M, P
14	3,085–3,170	3,080–3,143		51				1,250	0	0	44	38	41	0.27	P
15	1,536	1,529		203		8		*x*	0	0	22	19	20.5	0.30	A
16	2,447	2,349[12]						1,125	155	117					
17	3,237	3,175		35				1,350	0	0	42	38	40	0.30	P
18	2,440	2,280		81				750	0	0	45.5	38	40	0.10	P
19	2,344	2,336						1,080	1,060	1,061					
20	804	794						0	0	0					
21	2,851	2,838		7				900	800	7*xx*	45	38	41	0.22	P
22	5,676–6,014	5,560–5,891	38					2,400–1,150	1,985	2,050–1,150	47	42	45	0.10	P
23	4,420	4,314						1,800	1,020	600					
24	1,438	1,415						630	630	630					
25	1,922–3,232	1,617–3,150		68				[19]	[19]	[19]	46	42	43	0.15	P
26			38	2,581		8									
27	1,944	1,833[13]	1	43				295–500	0–140	0–200	26–34.5	21–34.5	28	0.17	A
28	1,506	1,351[14]		4				200	30	30	24	22	23	0.37	A
29	1,158	1,148		17				50	0	0	22.6	22	22.3	0.15	A
30	2,752	2,685[16]	1	81				*x*	55	220	32	20	29.4	0.30	A

[7] Average depth of all wells completed.

[8] Productive horizons and average depth to top of horizons are as follows: Nacotoch, 1000 ft.; Buckrange, 1823 ft.; Tokio, 2260 ft.; Trinity, 3647 ft.

[9] Average bottoms of wells and tops of productive zones are as follows: 840–804 ft.; 1556–1548; 1915–1896 and 2496–2469 ft.

[10] Also produces from contact of Upper and Lower Cretaceous, contact of Washita and Fredericksburg, Glen Rose and Lower Glen Rose. The producing horizons are found at the following average depths: Nacatoch sand, 1000 ft.; Buckrange, 1950; 2300-ft. horizon, 2250–2350; Adams sand, 2600–2700; Augurs 2900–3000; 3100–3200 and, 3300-ft. sands; 1st Lower Glen Rose horizon, 4645 ft.; 2d Glen Rose horizon, 4697 ft.

[11] Producing horizons: 845 883 ft., 1710–1745 ft., 2445–2480 ft., 2750 ft. sd., 3200 ft. sd., 4108–4275 ft.; Nacatoch wells dead, 1700 ft. sd. 235 lb., 2400 ft. sd. 220 lb., 4200 ft. sd. 1750 lb.

[12] One well completed in the Glen Rose at 2936 ft.

[13] Production obtained from following zones: 1515–2075 ft.; 3915–4330 ft., 7300–7392 ft.; 7683–7803 ft.; and 8600–8760 ft.

[14] Production obtained from following zones: 400–760 ft.; 1380–1535 ft.; and 1645–1890 ft.

[15] Production obtained from following zones: 1100–1170 ft.; 1510–2150 ft., 2050–2440 ft., 2600–2800, 2915-3272, and 3395 -3665 ft.

[17] Pressures and saturation in Blanchard area.

[18] Pressures on Augurs sand. Pressures on Nacatoch 65 lb.; 2300 ft. sand, 200 lb.; 2600 ft. sand, 210 lb.

[19] Wells flow for a few days after acid treatment.

The discovery well was drilled down dip from the gas area and was completed in the Young horizon. The tops or markers on the producing horizons and the thicknesses in the discovery well were: Hill sand, 5657 to 5696 ft.; Gloyd oolitic limestone (Caddo Levee Board gas sand), 6772 to 5854 ft.; Dees sand 5914 to 5927 ft.; Young limestone (coquina),

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1935		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935[46]	Deepest Zone Tested to End of 1935	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1	926	0.22[17]	8	CreU, CreL	C, S	Por	16	A	897	L Trinity	6,351
2	*y*	0	Nacatoch, "Chalk Rock," Basal CretU, Glen Rose	CreU, CreL	S	Por	19	AF	309	Glen Rose	6,141
3			Ozan, Tokio	CreU	S	Por	35	D	11	CreL	3,002
4	1,025	0.15[43]	Nacatoch, Ozan, Tokio	CreU	S	Por	8	A	42	CreL	5,382
5	1,017	0.13	"Monroe Gas Rock"	CreU	LS	23	50	A	100	Glen Rose	4,155
6	*x*	0.24	Nacatoch, Buckrange	CreU, CreL	S, L	Por	120	A	51	Glen Rose	3,575
7	3,300	15.0[44]	Nacatoch, Buckrange[45]	CreU	S	Por	63	DF	196	Glen Rose	4,504
8	1,100	1.50[44]	Buckrange, Glen Rose	CreU, CreL	S	Por	25	A	61	Glen Rose	5,092
9	971	0	Buckrange	CreU	S	Por	12	A	26	Glen Rose	4,750
10	970	0.34	Nacatoch, Buckrange, Lewer Glen Rose	CreU, CreL	S	Por	8	DF	109	L Trinity	6,137
11	972–1,057	0 0.24	Nacatoch, Buckrange, Tokio, Fredericksburg, Glen Rose	CreU, CreL	S, L	Por	100	D	5	Glen Rose	4,276
12	994–1,046	0.07 0.33	Buckrange, Tokio	CreU	S	Por	11	A	19	Glen Rose	5,120
13	866–1,004	1.5	Buckrange, Glen Rose	CreU, CreL	S, A, S	27, 24	11	A	26	L Trinity	7,006
14	994 1,046	0.07 0.33	Buckrange, Tokio	CreU	S	Por	16	A	49	Trinity?	3,476
15			Cane River—Wilcox Contact	Eoc	S	Por	9	MU	145	Tokio	6,463
16	1,060	0.34	Tokio, "Monroe Gas Rock," Glen Rose	CreU, CreL	S, LS	Por	76	A	39	L Trinity	2,836
17			Washita	CreL	S	Por	16	A	24	Glen Rose	5,063
18			Saratoga, Marlbrook, Anona, Ozan	CreU	C, S	CreU	8	AF	407	Glen Rose	7,155
19	998	0	"Monroe Gas Rock"	CreU	LS	Por	8	D	10	Glen Rose[47]	3,142
20			Basal Jackson	Eoc	S	Por	9	NF	8	Wilcox	2,435
21			Eagle Ford	CreU	S	Por	11	N	27	Fredericksburg	3,373
22	1,060	0.50 0.40	Lower Glen Rose	CreL	LS	Por	25	AF	18	L Trinity	6,715
23	1,125	0.56	Glen Rose	CreL	L	Por	20	A	13	L Trinity	4,722
24	984	0	Basal Jackson	Eoc	S	Por	25	N	6	Wilcox	3,705
25			Nacatoch, Saratoga, Anona, Ozan, Washita	CreU, CreL	M, C, S	Por	10	D	61	Glen Rose	4,433
26									2,659		
27			"Fleming" Marginulina?	Mio	S	Por	55	DS	112	Vicksburg	8,903
28			Citronelle, "Fleming," Jackson	Pli, Mio, Eoc	S	Por	35	DS	79	Jackson	1,500[48]
29			Pli-Mio Contact	Pli, Mio	S	Por	8	D	43	Vicksburg	6,017
30			Pli L, Fleming, Discorbis, Marginulina	Pli, Mio	S	Por	90	DS	199	Jackson	6,553

43 Gasoline content of gas from deep horizon; gas from other sands is dry.
44 Produce casinghead gas.
45 Goes also under name of Oakes sand or Haynesville sand.
46 Dry holes drilled in fields and those drilled in defining producing limits.
47 Abandoned in igneous rock.
48 Deepest well abandoned at 6204 ft. in Miocene.

5940 to 5999 ft. (base saturation). Some writers have taken the top of the Gloyd zone at 5750 ft. In November, Vaughn Production Company's Hunter and Derryberry No. 1, sec. 14, 23 N. 16 W., was completed flowing 140 bbl. per hour from the Dees sand, to extend production to the north. It is possible that both the Hill and Gloyd horizons will produce farther to the north, as the Vaughn Production Company's Comegys No. 1, sec. 10, 23 N., 16 W., made 60,000,000 cu. ft. of gas per day when tested in the Gloyd sand. Thirty-seven oil wells have been completed to the end of 1935, proving about 3800 acres.

Lincoln Parish.—Herman L. Brown and others discovered another potential gas field in the Glen Rose of the Trinity, when Fowler No. 1, sec. 10, 17 N., 4 W., in the interior salt-dome area was completed at a total depth of 5303 ft., gaging 71,385,000 cu. ft. of wet gas with 2140 lb. rock pressure. Although the gas was heavily saturated with gasoline, no

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
31	Edgerly, *Calcasieu*	24	215	0	0	215	8,308,094	73,744	85,511	209
32	Pine Praire, *Evangeline*	24	10	0	0	10	20,000	0	0	
33	Houma, *Terrebonne*	24	0	0	720	720				
34	Bayou Bouillon, *St. Martin*	20	12	0	0	12	372,894	0	0	
35	New Iberia, *Iberia*	19	25	0	0	25	720,014	63,720	583,947	2,319
36	Lockport, *Calcasieu*	12	270	0	0	270	13,188,863	712,388	651,119	1,317
37	Starks, *Calcasieu*	11	50	0	0	50	2,028,229	264,760	193,397	497
38	Sulphur, *Calcasieu*	10	50	0	0	50	8,109,730	1,280,036	945,935	2,841
39	Sweet Lake, *Cameron*	10	250	0	0	250	2,805,925	386,725	407,726	1,114
40	Fausse Point, *Iberia*	9	10	0	0	10	31,726	0	0	
41	Hackberry, *Cameron*	8	80	0	0	80	2,259,674	191,835	164,185	348
42	East Hackberry, *Cameron*	8	140	0	0	140	12,475,790	1,728,862	2,425,928	7,489
43	Sorrento, *Ascension*	8	20	0	0	20	580,624[3a]	10,200	47,397	303
44	White Castle, *Iberville*	7	40	0	0	40	1,443,652	199,781	208,988	909
45	Port Barre, *St. Landry*	7	75	0	0	75	5,320,521	980,211	1,316,489	2,663
46	Dog Lake, *Terrebonne*	7	20	0	0	20	42,350	0	35,037	0
47	Bayou Blue, *Iberville*	7	30	0	0	30	61,837	0	0	
48	Black Bayou, *Cameron*	7	30	0	0	30	2,297,238	410,746	568,320	2,869
49	Lake Pelto, *Terrebonne*	7	20	0	0	20	194,055	1,271	35,133	504
50	Lake Barre, *Terrebonne*	7	100	0	0	100	12,966,928	1,797,082	2,833,396	9,285
51	Caillou Island, *Terrebonne*	6	50	0	0	50	5,036,713	1,362,782	3,325,211	9,104
52	Cameron Meadows, *Cameron*	5	40	0	0	40	1,612,499	479,864	1,056,100	4,409
53	Choctaw, *Iberville*	5	20	0	0	20	937,374	312,119	275,255	1,051
54	Lake Washington, *Plaquemines*	5	200	0	0	200	1,205,344	359,804	501,207	1,500
55	Leeville, *Lafourche*	5	210	0	0	210	9,877,254	4,268,595	4,820,093	14,048
56	Iowa, *Calcasieu, Jefferson Davis*	5	0	1,000	0	1,000	16,500,658	5,276,444	7,346,529	20,223
57	Darrow, *Ascension*	4	50	0	0	50	280,826	5,109	264,987	888

[3a] Estimated.

test of the content was made. The produeing horizon is below the anhydrite but probably above or possibly the equivalent of the Hill sand, the upper gas horizon in the Glen Rose at Rodessa.

Bossier Parish.—A new gas-producing area was opened up in De Soto Parish when Plain Dealing Syndicate's L. A. King No. 1, sec. 36, 23 N., 13 W., tested 5,000,000 cu. ft. of gas from the Ozan sand at 2833 to 2839 ft. The hole is bottomed at 2841 feet.

De Soto Parish.—Shortly after the discovery of oil at Rodessa, the Hunter Company completed De Soto No. 1, sec. 29, 12 N., 14 W., making 16,000,000 cu. ft. of gas daily. The well produced from 23 ft. of broken sand found from 2818 to 2841 feet.

Sligo.—The Sligo field was extended ¾ mile east when the United Gas Public Service Company's R. V. Kerr No. A-1, sec. 24, 17 N.,

TABLE 1.—(*Continued*)

	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1935		At End of 1935				
Line Number	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
31	38,642		12					177	2	0	0	20			20
32	2,000							4	0	0	0	0			0
33				14,295				10	0	0	0	0			0
34	31,074							10	0	0	0	0			0
35	28,800		773					9	4	0	2	3			3
36	48,847		49					81	1	0	3	27			27
37	40,564		29					27	1	0	1	18			18
38	162,194		55					79	9	0	0	52			52
39	11,223		186					9	1	0	0	6			6
40	3,172							4	0	0	0	0			0
41	28,245		17					54	1	0	1	21			21
42	89,112		129					116	14	4	3	56			56
43	29,031		76					9	3	0	2	4			4
44	36,091		152					7	4	0	0	7			7
45	70,940		92					42	6	0	1	28			28
46	2,085		0					2	1	0	0	1			1
47	2,061							6	0	0	0	0			0
48	76,574		205					19	6	0	0	14			14
49	13,624		504					3	1	0	0	1			1
50	120,813		442					37	6	0	1	21			21
51	92,380		910					13	5	0	0	12			12
52	40,312		245					20	12	0	0	18			18
53	46,868		150					10	3	0	0	7			7
54	6,021		125					16	0	0	3	12			12
55	47,532		198					88	17	0	0	73			73
56	16,500		349	4,784	185	4,599	14	66	15	5	0		58		58
57	5,616		148					6	4	0	0	6			6

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1935					Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935				
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells				Injection into Reservoir[d]	Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]
			Flowing	Pumping	Gas-lift	Air-lift			1934	1935	Maximum	Minimum	Weighted Average		
31	3,145	3,107[16]		20				*x*	50	0	22	19	20	0.18	A
32	1,269	1,200						*x*	0	0					
33	2,469	2,448						1,040	0	0					
34	3,050	2,838[20]						1,600	0	0					
35	2,458	2,398[21]	1	2				400	400	*y*	24.9	24.9	24.9	0.26	A
36	4,558	4,533[22]	9	13		5		2,200	775	345	41	23	33	0.12	A
37	2,272	2,224[23]	2	16				700	197	200	32	18	25	0.30	A
38	4,160	4,136[24]	12	30		10		850	150	91	36	19	26	0.31	A
39	6,284	6,262[25]	4	2				1,050	147	215	32	29	28.5	0.12	A
40	1,170	1,137						*x*	0	0					
41	3,331	3,296[26]		21				500	92	0	32	19	20	0.37	A
42	3,700	3,668[27]	16	40			G	2,400	1,625	735	32	20	28	0.44	A
43	1,639–4,351	1,624–4,338	1	3				325–1,650	325–1,600	325–1,050	31	26	28	0.38	A
44	5,188–5,836	5,170[28]–5,700	3	2	2			875	250	465	26.5	24.2	25	0.36	A
45	3,407	3,368[29]	4	22				640–725	350	300–625	33.7	25	27	0.33	A
46	1,068–7,125	1,056–7,101	1					1,300	0	*y*	38.5	38.5	38.5	0.22	A
47	2,319	2,262[30]						300	0	0					
48	4,535	4,446[31]	10	1	3			600	205	205	23.8	18	21	0.11	A
49	1,373–6,270	1,274–6,248	1					675	0	*y*	34.3	34.3	34.3	0.55	A
50	3,836	3,777[32]	19	2				600	193	*y*	35.5	33	34	0.32	A
51	4,555	4,510[33]	12					620–1,032	620–1,032	6*xx*–10*xx*	34	32	33	0.26	A
52	4,113	4,080[34]	11	7				1,500	791	1,072	41	27	37	1.0	A
53	3,107	3,052[35]	3	4				600–1,600	400	500–1,600	29.6	26.4	28.2	0.15	A
54	1,154	1,135	12					450	160	144	19	18	18.5	0.73	A
55	3,729	3,660[36]	24	44	7	2		1,300	315	1*xx*	29.2	22.9	26	0.40	A
56	6,941	6,920[37]	56		2			2,510	1,400	1,050	49.7	25.4	41	0.37	M
57	[38]	[38]	3	2				875–1,200–2,000	0	875–1,200–2,000	41.6	34.1	37.8	0.12	A

[16] Production obtained from following horizons: 1060–1558 ft., 2314–2355 ft.; 2655–2795 ft.; 2890–2920 ft.; 3205–3095 ft.; 3100–3264 ft.; 3405–3650 ft., 3680–3740, 3910–4055 ft.

[20] Production obtained from following horizons: 410–450 ft.; 3025–3210 ft.; 3235–3360 ft.; and 4284–4341 ft.

[21] Producing zones: 1008–1070 ft.; 1665–1710 ft.; 2690–2855 ft.; 3805–3828 ft.; 4476–4500 ft., 4592 ft., 4650–4737 ft., 5385–5401 ft.

[22] Producing zones: 1000–1095 ft., 2960–3237; 3385–3400; 3620–3875; 4315–4435; 4705–4924; 5100–5665; 5970–5985; and 6445–6623 ft.

[23] Producing zones: 535–570 ft., 746–910; 1205–1240 C.R.; 1080–1278 Sd.; 2300–2315 ft.; 3000–3020; 3400–3420; 3690–3721; 4175–4288; 4436–4481; 4759–4795 ft.

[24] Producing zones: 2760–2950; 3150–3575; 3650–3835; 3985–4200; 4300–4525; 4775–5175; and 5325–5700 ft.

[25] Producing zones: 5170–5195; 5632–5718; 5900–5925; 6795–6815; and 7335–7387 ft.

[26] Producing zones: 3010–3400; 3810–3975; and 4275–4350 ft.

[27] Producing zones: 2610–3100; 3900–4015; 5990–6140; and 7232–7242 ft.

[28] Producing zones: 5170–5188; 5700–6042; 6546–6559; 8894–8902; and 8925–8942 ft.

[29] Producing zones: 3150–3200; 3320–3420; and 3710–3717; 4867–4883 ft.

[30] Producing zones: 1710–1735; 1900–2300; and 3575–3590 ft.

[31] Producing zones: 965–980; 4380–4520; 5080–5220; and 6615–6630 ft.

[32] Production from sands between 3650–4080 ft.

[33] Producing zones: 3206–3243; 3965–4006; and 5980–6030 ft.

[34] Producing zones: 3310–3375; 3510–3580; 3770–3850; 3904–4100; 4243–4259; 4325–4410; and 5263–5273 ft.

[35] Producing zones: 2030–2050; 2410–2560; 2880–2900; 4100–4400; 4515–4581; and 5413–5473 ft.

[36] Oil and/or gas produced from sands found at the following average depths; 2800–3000; 3300, 3560, 3670, 3760, 3837, 4200, and 4400 ft.

[37] Production obtained from sands found at the following average depths: 4515, 5135, 5585, 6525, 6935. Most wells have been deepened to or completed in the zone of 6935 ft.

[38] Producing zones: 4008–4035; 4820–4827; 5488–5513; and 5669–5686 ft.

12 W., Bossier Parish, yielded 36,000,000 cu. ft. of gas daily, completed at 4295 ft. in the Glen Rose.

Pine Island.—Minor extensions were made on the north and east side of the old Pine Island field.

South Louisiana

Lafitte.—The Lafitte or Bayou St. Dennis field, 22 miles south of New Orleans, was discovered by the Texas Company's Bayou St. Dennis No. 1, sec. 19, 17 S., 24 E., Jefferson Parish. On the first 24-hr. gage, the

Table 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1935		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935[46]	Deepest Zone Tested to End of 1935	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
31			Pli L	Pli	S	Por	130	DS	88	Jackson?	8,414
32			"Fleming"	Mio	S	Por	30	DS	31	"Fleming"	5,112
33			Upper Marine Mio	Mio	S	Por	10	D	13	Miocene	5,645
34			"Fleming"	Mio	S	Por	28	DS	43	Vicksburg	3,910[49]
35			Pli L "Fleming"	Pli, Mio	S	Por	46	DS	36	L Miocene	7,934
36			"Fleming," Heterostegina	Mio	S	Por	100	D	18	Marginulina?	7,902
37			PliL, Cap rock, "Fleming" MioL	Pli, Mio	S	Por	40	DS	57	Jackson?[52]	7,207
38			"Fleming," Heterostegina	Mio	S	Por	120	DS	38	Heterostegina?	9,250[53]
39			"Fleming"	Mio	S	Por	40	DS	6	Mio?	8,070
40			"Fleming"	Mio	S	Por	7	DS	17	"Fleming"	5,119
41			"Fleming"	Mio	S	Por	35	DS	107	Jackson?[52]	3,424[54]
42			"Fleming"	Mio	S	Por	65	DS	67	Jackson?[52]	3,035[55]
43			Cap rock, Vicksburg	X, Olig	A, S	Por	45	DS	25	Vicksburg	5,725[56]
44			"Fleming"	Mio	S	Por	30	DS	4	"Fleming"	8,942
45			Marginulina?	Mio	S	Por	35	DS	20	Heterostegina	4,883
46			PliL	Plio	S	Por	12	DS	14	MioU	7,128
47			"Fleming"	Mio	S	Por	20	DS	10	"Fleming"	6,103
48			Cap rock, MioU, Heterostegina	X, Mio	L, S	Por	120	DS	22[50]	Marginulina?	6,200[57]
49			Upper Marine Mio	Mio	S	Por	55	DS	8	MioU	7,039
50			Upper Marine Mio	Mio	S	Por	75	DS	16	MioU	7,162
51			Upper Marine Mio	Mio	S	Por	90	DS	12	MioU	6,017
52			"Fleming"	Mio	S	Por	40	DS	5	MioU	9,331
53			"Fleming"	Mio	S	Por	40	DS	14[51]	"Fleming"	6,290
54			Cap rock, Super Cap sand	X, Plio	L, S	Por	26	DS	30	Mio	5,860[58]
55			Upper Marine Mio	Mio	S	Por	120	DS	16	MioU	7,300[53]
56	1,102	0.50	"Fleming," Heterostegina, Marginulina	Mio	S	Por	53	D	9	Marginulina	7,590
57			Upper Marine Mio	Mio	S	Por	34	DS	10	MioU	6,901

49 Deepest well abandoned at 6471 ft. in Lower Miocene.
50 Includes 7 sulfur tests.
51 Includes 8 sulfur tests.
52 Abandoned in heaving shale.
53 Abandoned in salt.
54 Deepest well abandoned at 7834 ft.
55 Deepest well abandoned at 8384 ft.
56 Deepest well abandoned at 6565 ft.
57 Deepest test abandoned at 6905 ft.
58 Abandoned in salt at 6179 ft.

well made 2410 bbl. of 34.9° A.P.I. oil per day through a $\frac{3}{8}$-in. choke with a 1600-lb. tubing pressure from middle Miocene sands found from 9558 to 9572 ft., the total depth. Not only did this well open up a new field; it establishes a new producing record for the Gulf Coast and the first commercial production in Jefferson Parish. This is a deep-seated dome and early development indicates that this horizon will result in sustained production.

Garden Island Bay.—In September, 1935, the Texas Company completed its Garden Island Bay No. 16, sec. 37, 23 S., 33 E., Plaquemines Parish, for an initial production of 525 bbl. of 37.2° A.P.I. oil per day through a $\frac{1}{4}$-in. choke with a tubing pressure of 850 lb. and casing pressure of 660 lb. The well is producing from a Miocene sand found from 4915 to 4930 ft., total depth. This was the thirteenth well drilled on the dome. Garden Island No. 11 was completed as a gas well. With the exception of Garden Island No. 5, which was abandoned at 5618 ft. and failed to develop important showings, all previous tests were abandoned in salt or cratered and were completed at shallow depths. This field demonstrates the number of dry holes required to outline flank production.

Tepatate.—The Tepatate field, north of the old Jennings field in Acadia Parish, was discovered by the Continental Oil Co. The discovery well, Theogen Ortego No. 1, sec. 28, 7 S., 2 W., was completed flowing 745 bbl. of 37° A.P.I. oil and 4,000,000 cu. ft. of gas per day through a $\frac{1}{4}$-in. choke with a tubing and casing pressure of 2275 and

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
58	Gueydan, *Vermilion*	4	50	0	0	50	572,008	104,853	82,747	213
59	Bosco, *Acadia, St. Landry*	2	1,250	0	0	1,250	7,433,593	1,061,878	6,371,715	16,522
60	Lake Hermitage, *Plaquemines*	2	10	0	0	10	71,258	405	70,853	208
61	Roanoke, *Jefferson, Davis*	2	200	0	0	200	1,858,298	238,736	1,619,562	5,794
62	Four Isle, *Terrebonne*	2	20	0	0	20	79,432	20,412	59,020	431
63	Gillis, *Calcasieu*	2	300	0	0	300	2,143,112	48,362	2,094,750	1,035
64	Lafitte, *Jefferson*	1	50	0	0	50	431,525		431,525	3,264
65	Tepatate, *Acadia*	1	100	0	0	100	131,764		131,764	1,583
66	Bunkie, *Rapides*	1	0	20	0	20	8,919		8,919	34
67	St. Martinville, *St. Martin*	1	0	20	0	20	28,352		28,352	0
68	Jeanerette, *St. Mary*	1	20	0	0	20	2,814		2,814	0
69	Garden Island Bay, *Plaquemines*	1	10	0	0	10	52,305		52,305	1,013
70	Total South Louisiana		4,602	1,040	720	6,362	214,878,188	23,255,437	40,731,056	117,938
71	Total Louisiana		129,302	11,544	232,380	373,226	615,628,423	32,529,487	50,348,461	150,493

2900 lb., respectively. Oil sand was found from 8277 to 8313 ft. in the Marginulina zone. The Continental has a large block, taken after extensive geophysical work. Five wells have been completed, to the end of 1935. It is probable that the Continential Oil Company's Henry Klump No. 1, sec. 30, 7 S., 2 W., is producing from a higher horizon than the discovery well, as the gravity is 32° A.P.I. The oil from the Home-seekers Development Co. No. 1 and Mrs. Eddy Kern No. 1 wells has a gravity of 44° A.P.I., while that from the Federal Land Bank No. 1, and the Theogen Ortego No. 1 is 37° to 38° A.P.I. Henry Klump No. 1 was drilled to 9000 ft. to the Vicksburg and plugged back. The sand section is probably not continuous, but consists of two or three sands separated by thin shale bodies.

Bunkie.—The Amerada Petroleum Corporation's Weil No. 1, sec. 57, 1 S., 2 E., Rapides Parish, was the discovery well for Louisiana's first "Conroe Trend" field. The well produced initially 154 bbl. of 53.9° A.P.I. oil and 2,500,000 cu. ft. of gas through a ¼-in. choke from a Cockfield sand from 5704 to 5710 ft. The total depth was 6838 ft., at which point the well was probably in the Cook Mountain. This well is of great importance because it not only opens up a large area for future exploration, but, based on geophysical work, proves up a good-sized structure. Gas sands were encountered from 5611 to 5641, from 5726 to 5727, and from 5758 to 5771 feet.

St. Martinsville.—Completion by Tidewater Oil Co. of a producing well at St. Martinsville, St. Martin Parish, opened up the fifth new field

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Producing Oil and Gas[c]	At End of 1935: Producing Gas Only	At End of 1935: Total Producing
58	11,440		53					5	0	0	0	4			4
59	5,946		275					69	48	1	3	65			65
60	7,125		208					2	1	0	1	1			1
61	9,241		446					15	11	1	0	14			14
62	11,855		431					2	1	0	1	1			1
63	7,143		38					32	30	0	2	30			30
64	864		1,088					3	3	0	0	3			3
65	1,318		396					5	5	0	0	5			5
66	445		34	111		111	3	1	1	0	0	0	1		1
67	1,417		0	21		21	y	1	1	0	0	0	1		1
68	140		0					1	1	0	0	1			1
69	8,597		1,013					1	1	0	0	1			1
70								2,120	225	11	25	679	60	0	739
71								12,159	444	22	50	2,602	754		

on the Louisiana Gulf Coast. A previous test drilled several years ago, a short distance from the discovery well, had several shows of oil and gas but of insufficient thickness to test. Numerous gas seeps and paraffin dirt, together with several different geophysical pictures, have kept the area active for the past five years. The discovery well, Smedes No. 1, sec. 57, 11 S., 6 W., was completed flowing 200 bbl. of 32° A.P.I. oil and 5,000,000 cu. ft. of gas per day through a ⅜-in. choke with a tubing pressure of 1975 lb. and a casing pressure of 2090 lb. After producing for a short time, the well was flowing 1000 bbl. per day. It is producing from the Shoal River, middle Miocene, in sand found from 5557 to 5582 ft., total depth. As might be expected, subsequent drilling has proved this sand to be lenticular and resulted in dry holes offsetting the producer. A deep test is now being drilled, which should be productive in the Discorbis, Heterostegina or Marginulina zones of the lower Miocene.

Jeanerette.—The sixth new oil field for South Louisiana and the first commercial production in St. Mary Parish was discovered by the Herton Oil Co. Roane No. 1, sec. 40, 13 S., 9 E., was completed flowing 700 bbl. of 40.7° A.P.I. oil per day through a ¼-in. choke with casing and tubing pressure of 1200 lb. The well came in flowing from upper Miocene sand found from 7488 to 7498 ft. after being plugged back from 7514 feet.

Big Lake.—The Big Lake field was opened in December, 1935, by the completion of Magnolia Petroleum Company's Broussard No. 1, sec. 13,

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1935					Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935				
			Number of Wells						Average at End of		Gravity A.P.I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Injection into Reservoir[d]	Initial	1934	1935	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
58	3,972	3,924[39]	1	3				1,150	50	30	27.5	27.1	27.3	0.12	A
59	[40]	[40]	58		7		G	900–3,100	2,150	1,600	45.6	36	38.5	0.17	M
60	3191–4,269	3,176–4,257	1					850	0	850	32.1	32.1	32.1	0.06	A
61	8,477	8,454[41]	12					2,025	2,025	1,800	38.4	37	38	0.10	M
62	5,642	5,512	1					980	980	y	44.5	44.3	44.4	0.18	M
63	[42]	[42]	30				G	1,730–2,650	1,100	1,005–1,875	34.1	34.1	34.1	0.68	A
64	9,555	9,575	3					1,500	0	1,500	35	35	35	0.19	A
65	8,315	8,275	5					2,300	0	2,300	44.5	32	37	0.34	M
66	5,710	5,704	1					y	0	y	53.9	53.9	53.9	0.30	A
67	5,582	5,557	1					1,980	0	1,980	32	32	32	0.21	A
68	7,498	7,488	1					1,200	0	1,200	40.7	40.7	40.7	0.31	M
69	4,930	4,921	1					y	0	y	37.2	37.2	37.2	0.25	A
70															
71															

[39] Producing zones: 3450–3555; 3890–4300; and 4820–4850 ft.
[40] Producing zones: 7830–7760; 8050–8090; 8420–8500; 8620–8700; 8750–8800; 9004–9024; and 9018–9028 ft.
[41] Producing zones: 7796–7918; 8660–8682; 8814 8830; and 9314–9345 ft.
[42] Producin7 zones: 5156–5180; 6413–6419; 6710–6767; 7005–7085; and 9242–7246 ft.

12 S., 9 W., good for 25 bbl. of 48.2 A.P.I. oil and 20,000,000 cu. ft. of gas per day through a ¼-in. choke with a tubing pressure of 2950 ft. The hole was drilled to a total depth of 9501 ft., casing was set, and the well tested at progressively shallower depths. Tests in four formations below the one in which the well was completed resulted in salt water.

New Sands around Old Fields

A number of new areas and new producing sands were discovered during the past year. Flank production was opened at Port Barre by the Pan American Producing Company's Haas Hirsch No. 1, completed flowing 1036 bbl. of 36° A.P.I. oil through a ⅜-in. choke from a sand between 4867 and 4883 ft. New sands were found at Roanoke, Jefferson Davis Parish; New Iberia, Iberia Parish; Sorrento, Ascension Parish; White Castle, Iberville Parish; Dog Lake, Terrebonne Parish; Lake Pelto, Terrebonne Parish; Choctaw, Iberville Parish; Lake Washington, Plaquemines Parish; Darrow, Ascension Parish; Bosco, Acadia and St. Landry Parishes; Lake Hermitage, Plaquemines Parish; Gillis, Calcasieu Parish; Cameron Meadows, Cameron Parish; Jennings, Acadia Parish.

The discovery wells of the new sands in the old fields mentioned are listed in Table 2.

Table 1.—(*Continued*)

	Character of Gas Approx. Average during 1935		Producing Rock							Deepest Zone Tested to End of 1935	
Line Number	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935[46]	Name	Depth of Hole, Ft.
58			"Fleming"	Mio	S	Por	31	DS	9	Discorbis	9,545[59]
59			Discorbis, Heterostegina, Marginulina	Mio	S	Por	90	D	10	Vicksburg	10,005
60			Upper Marine Mio	Mio	S	Por	15	DS	14	MioU	6,472
61			Heterostegina, Marginulina	Mio	S	Por	50	D	13	Marginulina	10,750
62			Upper Marine Mio	Mio	S	Por	28	DS	9	MioU	6,923
63			Marginulina	Mio	S	Por	15	D	10	Marginulina	9,246
64			Miocene	Mio	S	Por	45	D	0	Miocene	9,633
65			Marginulina	Mio	S	Por	35	D	1	Vicksburg	9,000
66	1,146	0.75	Cockfield	Eoc	S	Por	10	D	0	Cook Mountain	6,838
67	1,019	0.03	Shoal River	Mio	S	Por	25	D	0	Miocene	7,454[59]
68			Upper Marine Mio	Mio	S	Por	10	D	0	Miocene	7,514
69			Upper Marine Mio	Mio	S	Por	15	DS	12	Miocene	5,618
70									603		
71									3,262		

[59] Drilling.

Acknowledgments

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Table 2.—*Summary of Drilling Operations in Louisiana*

Important Wildcats Drilled in 1935

	County	Location			Total Depth, Ft.	Surface Formation
		Section	Township, Lat.	Range, Long.		
1	Catahoula	2	9 N.	6 E.	943	Catahoula
2	Iberia—Iberia	54	12 S.	7 E.	5,401	Recent
3	Iberia—Iberia	54	12 S.	7 E.	2,802	Recent
4	Iberia—Iberia	54	12 S.	7 E.	4,915	Recent
5	Calcasieu—Gillis	14	9 S.	8 W.	8,580	Recent
6	Calcasieu—Gillis	12	9 S.	8 W.	7,694	Recent
7	Iberville—White Castle	1	11 S.	12 E.	8,919	Recent
8	Iberville—White Castle	1	11 S.	12 E.	8,942	Recent
9	Iberia—Iberia	56	12 S.	7 E.	5,647	Recent
10	Iberia—Iberia	56	12 S.	7 E.	4,500	Recent
11	Acadia—Bosco	34	8 S.	3 E.	9,118	Recent
12	Acadia—Bosco	34	8 S.	3 E.	9,034	Recent
13	East Baton Rouge	65	7 S.	1 E.	10,360	Recent
14	Jeff. Davis—Roanoke	12	9 S.	4 W.	7,830	Recent
15	Calcasieu—Gillis	14	9 S.	8 W.	9,246	Recent
16	Plaquemines—Hermitage	11	18 S.	25 E.	3,191	Recent
17	Calcasieu-Gillis	13	9 S.	8 W.	7,063	Recent
18	Acadia—Jennings	47	9 S.	2 W.	7,804	Recent
19	Plaquemines—Washington	14	20 S.	26 E.	4,355	Recent
20	Ascension—Darrow	33	10 S.	2 E.	5,781	Recent
21	Ascension—Darrow	30	10 S.	2 E.	5,513	Recent
22	Ascension—Darrow	31	10 S.	2 E.	5,686	Recent
23	Jeff. Davis—Roanoke	14	9 S.	4 W.	9,425	Recent
24	Cameron—Cameron M	15	14 S.	10 W.	9,331	Recent
25	Cameron—Cameron M	21	14 S.	13 W.	4,259	Recent
26	Cameron—Cameron M	21	14 S.	13 W.	3,362	Recent
27	Iberville—White Castle	1	11 S.	12 E.	6,564	Recent
28	Terrebonne—L. Pelto	12	17 S.	8 E.	7,039	Recent
29	Ascension—Sorrento	15	10 S.	4 E.	4,352	Recent
30	Iberville—Choctaw	52	9 S.	11 E.	4,581	Recent
31	Iberville—Choctaw	52	9 S.	11 E.	5,473	Recent
32	Calcasieu—Gillis	11	9 S.	8 W.	6,767	Recent
33	St. Landry—Pt. Barre	4	6 S.	5 E.	4,883	Recent
34	Terrebonne—Dog L.	5	22 S.	16 E.	7,128	Recent
35	Iberville—White Castle	1	11 S.	12 E.	6,042	Recent

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1935

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of In.	Pressure, Lb. per Sq. In.		Producing Depths
			Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Basal Jackson	Phillipi & Associates		0.15	Open flow	298		
2	Miocene	Texas—Hanzen No. 1-B	1,920		½		650	5,385–5,401 ft.[1]
3	Miocene	Canal—Sabatier No. 2	264		y	y	y	2,758–2,802 ft.[1]
4	Miocene	Hellis—Bernard No. 3	360		3/16	1,000	600	4,650–4,737 ft.[1]
5	Vicksburg?	Union Sulphur—Castle No. 3	600		¼		1,800	5,156–5,180 ft.[1]
6	Marginulina	Union Sulphur—State No. 12		y	¼		2,400	7,525–7,563 ft.[1]
7	Miocene	Shell Pet. Corp.—Adams No. 1	550		¼	1,220	1,050	8,894–8,902 ft.[1]
8	Miocene	Shell Pet. Corp.—Adams No. 1	125		23/64		130	8,925–8,942 ft.[1]
9	Miocene	Canal—Bernard No. 4	350		½		475	4,592 ft.
10	Miocene	Canal—Bernard No. 4	816		y		y	4,476–4,500 ft.[2]
11	Marginulina	Superior—L. Johnson No. 1	201		9/64		1,375	9,018–9,028 ft.[1]
12	Marginulina	Superior—Projean No. 1	99		y	y	y	9,004–9,024 ft.[1]
13	Vicksburg	Superior—Duplantier No. 1						Dry hole
14	Heterostegina?	Humble—Taylor No. 1	1,123		y	2,800	1,675	7,796–7,830 ft.[1]
15	Vicksburg	Fohs—Airhart No. 1	Spray	y	y	y	y	9,242–9,246 ft.[3]
16	Miocene	Humble—LaFourche Lev. No. 3	456		¼	350	425	3,176–3,191 ft.[1]
17	Marginulina	Fohs—Castle No. 1	1,300		3/8	1,125	1,100	7,043–7,063 ft.[1]
18	Marginulina?	Yount-Lee—Houssiere No. 14	300		5/16		500	7,683–7,803 ft.[1]
19	Miocene	Humble—Cockrell No. 23	345		3/8	460	525	4,337–4,353 ft.[1]
20	Miocene	Humble—Gumbel No. 2	1,272		y	850	750	5,773–5,781 ft.[1]
21	Miocene	Humble—Community No. 5	610		y	y	y	5,488–5,513 ft.[1]
22	Miocene	Humble—Community No. 6	449		y	y	y	5,669–5,686 ft.[1]
23	Marginulina	Humble—Devilbiss No. 3	100	3	¼	1,200	1,100	9,314–9,345 ft.[1]
24	Salt at 9,318 ft.	Texas—Miami No. 1	125		y		50	3,977–3,996 ft.[1]
25	Miocene	Magnolia—Cam. Med. No. 13	665		y	y	y	4,243–4,259 ft.[1]
26	Miocene	Magnolia—Cam. Med. No. 11	425		y	y	y	3,339–3,362 ft.[1]
27	Miocene	Shell—Wilbert No. 9	754		3/8	787	465	6,546–6,559 ft.[1]
28	Miocene	Texas—L. Pelto No. 9	1,162		3/8		y	6,248–6,270 ft.[1]
29	Miocene	Athens—United Lands No. 1	2,080		23/64		1,050	4,338–4,347 ft.[1]
30	Miocene	Standard—Gay No. 5	500		¼	y	460	4,515–4,581 ft.[1]
31	Miocene	Standard—Gay No. 5	350		¼	880	415	5,413–5,473 ft.[1]
32	Miocene	Union Sulphur—Barbee No. 5	600		¼		1,850	6,413–6,419 ft.[1]
33	Heterostegina	Pan-Am.—Haas—Hirsh No. 1	1,036		3/8	x	725	4,867–4,883 ft.[1]
34	Miocene	Texas—Dog Lake No. 18	1,500		3/8		y	7,101–7,125 ft.[1]
35	Miocene	Shell—Wilbert No. 8	625		y	670	600	6,025–6,042 ft.[1]

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	98	59
Number of oil wells completed during 1935	341	7
Number of gas wells completed during 1935	100	4
Number of dry holes completed during 1935	141	110

[1] New sand.
[2] New sand, sanded up.
[3] Completed in upper sand at 7,084 feet.

Oil and Gas in Michigan during 1935

By Theron Wasson,* Member A.I.M.E.

(New York Meeting, February, 1936)

The state of Michigan showed considerable activity during 1935. The center of greatest interest was the Crystal field, which was unknown until March, 1935, and is an illustration of the effect of the unknown and unexpected on Michigan oil development. The fields of the state (Fig. 1) produced a total of 15,770,000 bbl. of oil in 1935, or about 5 million more than in 1934. In order to keep up this production 307 new oil wells were drilled, of which 88 were in the Crystal area, which produced 3,600,000 bbl. This field had a rapid development and reached its peak in October. Since that time increasing water encroachment has caused a rapid decline. The pay horizon at the top of the Monroe dolomite is only a few feet thick. Big producers were offset by dry holes or small wells. The discovery well, which was in section 11, Crystal township, Montcalm County, was drilled March 28, 1935. Its initial production was 5000 bbl. per day, and up to Dec. 31, 1935, had produced 350,000 bbl. of oil—close to one-tenth of the total production of the field to that date.

The Beaverton field, which was discovered at the close of 1934, did not develop rapidly. Four small producers were finished in the Dundee lime during the year. West Branch was active and at the end of the year had 97 producers, 72 of which were drilled during 1935. Most of the wells produce from the Dundee lime; a few are finished in the Traverse.

The Birch Run field deserves special mention, for it is the one area where consistent production continues to be found in the Berea sand at about 1500 ft. Wells are small, 20 now producing a total of about 300 bbl. per day of oil of fine quality.

The old Central Michigan producing area, extending from Mt. Pleasant through Yost to Porter, continued to be the principal producing area of the state and accounted for 10,370,000 bbl. from 660 producing wells. Ninety-three new wells were drilled in this territory. The Porter field, at the southeast end of this producing trend, was outstanding from the standpoint of production.

The old Leaton field of Isabella County added several new producers. Its production was greater than in 1934.

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In the preparation of Tables 1 and 2 particular attention was given to the producing areas of some of the older fields that in the past have

Fig. 1.—Location of Michigan oil and gas fields.

been roughly estimated. In most cases previously reported acreage has been reduced. Production figures used in the tables are presented by using estimated production for November and December.

Gas

The major gas development of the year was in the Six Lakes area, in Hinton and Millbrook townships, Mecosta, and in Belvidere township, Montcalm County; 54 wells were drilled in this area during the year. This new development is 5 miles west of Edmore and has been named Six Lakes by local operators to distinguish it from the old Edmore oil field. Production is from the so-called "Michigan Stray sand" and the Marshall, at a depth of approximately 1300 ft. Some wells have had an initial production as high as 35 million cubic feet per day. Sand conditions appear to be much better than in other gas areas of the state. A 10-in. line is now under construction from the field to the city of Lansing. A Grand Rapids company has asked for approval from the State Securities Commission to build a line from the field to the city of

TABLE 1.—*Oil and Gas Production in Michigan during* 1935

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.				Average Oil Production, Bbl.	
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935
1	Saginaw, *Saginaw*	11	1,660	0	0	1,660	1,218,477	48,226	30,747	75	734	1
2	Muskegon, *Muskegon*	8	4,200	200	0	4,400	6,337,860	158,425	101,197	228	1,439	2
3	Mt. Pleasant, *Midland-Isabella*	8	9,680	0	0	9,680	18,161,274	1,557,339	1,257,762	3,072	1,876	10
4	Leaton, *Isabella*	6	1,500	0	160	1,660	1,438,105	200,544	256,629	675	1,058	18
5	Vernon, *Isabella*	6	1,000	0	880	1,880	2,646,938	907,239	611,855	880	2,647	22
6	Porter-Yost, *Midland*	4	8,000	0	0	8,000	20,242,791	7,443,968	9,197,476	16,868	2,530	46
7	Hart, *Oceana*	3	500	0	0	500	116,275	58,814	11,279	0	233	0
8	West Branch, *Ogemaw*	2½	5,000	0	0	5,000	663,121	124,922	519,285	2,133	133	22
9	Edmore, *Montcalm*	2	0	160	0	160	211,042	102,600	106,781	338	1,319	48
10	Gratiot, *Gratiot*	9	0	0	400	400	0	0	0	0	0	0
11	Clare, *Clare*	6	0	0	300	300	0	0	0	0	0	0
12	Broomfield, *Isabella*	6	0	0	5,700	5,700	541	366	175	0		0
13	Big Rapids, *Mecosta*	2½	0	0	2,500	2,500	0	0	0	0	0	0
14	Beaverton, *Gladwin*	1	300	0	0	300	23,475	0	23,475	129	78	32
15	Crystal, *Montcalm*	9 Mos.	1,400	200	*x*	1,600	3,600,677	0	3,600,677	19,997	2,250	238
16	Birch Run, *Saginaw*	1	250	0	0	250	40,562	7,000	33,562	215	162	11
17	Six Lakes, *Montcalm-Mecosta*	1	0	0	13,500	13,500	0	0	0	0	0	0
18	Miscellaneous, *Cass-Mason-Midland-Saginaw*						19,097		19,097			
19	Total		33,490	560	23,440	57.490	54,720,235	10,609,483	15,769,897			

[a] Footnotes to column heads and explanations of symbols are given on page 215.

Grand Rapids. At the close of the year, 15 wells were drilling and although the field has not been completely outlined it is apparent that a large area will be proved productive.

The Big Rapids gas field, Austin township, Mecosta County, now has 16 producing gas wells with a combined open flow of approximately 160 million cubic feet. One of the largest gas wells in Michigan was recently completed in this field, with an initial open flow of 50 million cubic feet. Gas from Big Rapids is bought by the American Michigan Pipeline Co. and sold for domestic consumption in Muskegon and Big Rapids.

The old Broomfield gas field was active throughout the year. No large producers were developed. Gas in this field is purchased by the Consumers Power Co. and sold for domestic consumption in Midland, Bay City and Saginaw. Some exploration for gas took place in other

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.: To End 1935	Total Gas Production: During 1934	Total Gas Production: During 1935	Maximum Daily during 1935	Number of Oil and/or Gas Wells: Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Producing Oil Only	At End of 1935: Producing Oil and Gas[c]	At End of 1935: Producing Gas Only	At End of 1935: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Flowing	Pumping	Injection into Reservoir[d]
1	0	0	0	0	282	0	25	76	0	0	76	1,850	1,820	0	76	0
2	6,132	432	407	1	411	1	21	120	y	25	145	2,075	2,050	0	120	0
3	1,486	628	M 730 F 127	2	413	19	29	232	76	0	308	3,575	3,510	0	327	G1
4	x	x	F 9	⅕	64	27	3	37	0	3	40	G-1,245 O-3,700	1,240 3,675	0	49	0
5	895	263	M 298	1	80	7	21	40	y	15	55	G-1,405 O-3,725	1,395 3,700	0	40	0
6	x	229	M & F 1,575	5	387	80	11	207	156	0	363	3,450	3,405	12	351	0
7	0	0	0	0	22	0	12	4	0	0	4	1,890	1,880	0	4	0
8	x	x	F 3	1/30	102	72	5	97	0	0	97	1,810 2,700	1,800 2,650	0	97	0
9	x	x	F 12	1/30	8	5	1	7	0	1	8	G-1,330 O-3,115	1,325 3,110	0	8	0 0
10	3	1	0	y	8	0	0	0	0	4	4	510	500			
11	y	0	y	y	7	0	0	0	0	7	7	1,420	1,415			0
12	3,428	1,235	M 1,265	41	58	14	0	0	0	53	53	1,350	1,300			0
13	1,035	199	M & F 736	33	16	8	0	0	0	16	16	1,410	1,390			0
14	0	0	0	0	4	4	0	4	0	0	4	3,885	3,870	0	4	0
15	F & Waste 136	0	F&Waste 136	2	92	92	4	84	0	4	88	3,190	3,185	12 est.	76	0
16	0	0	0	0	20	18	0	20	0	0	20	1,540	1,530	0	12	0
17	153	0	M & Air 153	2	60	54	0	0	0	60	60	1,300	1,275			
18	0	0	0	0	4	2		4	0	0	4			0	4	0
19	13,268	2,986	5,451		2,038	403	132	932	232	188	1,352					

gas areas reported in previous years but information on these can be obtained best by reference to Tables 1 and 2.

The Bureau of Mines, working in cooperation with the Public Utilities Commission and the Department of Conservation, has continued its study of the gas reserves in the Stray sands of Michigan. So far, the report has not been published.

Wildcatting

Wildcatting throughout Michigan was fairly active during the year, particularly around the Crystal field. One outstanding deep test on the Howell structure in section 35, Howell township, Livingston County, drilled through the Trenton limestone and into the St. Peter sandstone at a depth of 5890 ft., where it encountered a good flow of salt water. The St. Peter is the oldest geological formation tested to date in Michigan. Early in the year a test was completed in Sherman township, Newago

Table 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[e] Initial	Pressure, Average at End of 1934	Pressure, Average at End of 1935	Character of Oil, Approx. Average during 1935: Gravity A.P.I. at 60°F. Maximum	Gravity Minimum	Gravity Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity	Net Thickness, Average Ft.	Structure[i]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1933: Name	Depth of Hole in Feet
1	x	x	x	42	456	43	0.7	P			Berea	Mis L	S	Por	16	A	y	Sylvania	3,970
2	x	x	x	y	y	37	1.4	P	1,032	1	Traverse-Monroe	Dev	L-D	Por	10	A	y	St. Peter	4,754
3	x	x	x	y	y	42	0.2	P	y	75	Dundee	Dev	L	Por	15	A	26	Sylvania	4,821
4	x	x	x	y	y	43	0.4	P	y	y	Stray-Gas	Mis	S	Por	3	A	22	Monroe	4,390
											Dundee-Oil	Dev	L	Por	5				
5	575 x	x	265 to 500 x	y	y	44	0.5	P	1,046	y	Stray-Gas	Mis	S		5	Af	30	Monroe	3,700
											Monroe-Oil	Dev	L	Por	5				
6	x	x	x	y	y	42	0.3	P	y	1	Dundee	Dev	L	Por	15	A	22	Monroe	3,677
7	x	x	x	y	y	34	y	P			Traverse	Dev	L	Por	4	A	11	Dundee	2,407
8	x	x	x	y	y	36	0.3	P			Traverse	Dev	L	Por	5				
											Dundee	Dev	L	Por	15	A	15	Sylvania	5,404
9	900	600	x	y	y	42		P	y	y	Marshall	Mis	S		5	A	4	Monroe	3,700
											Traverse	Dev	S	Por	5				
10	x	x	x						y	y	Parma	Pen	S	Por	10	MCy	1	Dundee	3,100
11	600	600	556						1,042	y	Stray	Mis	S	Por	5	A	1	Monroe	4,055
12	550	x	221 to 516	y	y	46	x	P	y	y	Stray	Mis	S	Por	5	A	16	Monroe	3,787
13	515	x	483						1,051	y	Stray-Marshall	Mis	S	Por	10	A	5	Monroe y	3,798
14	x	x	x	y	y	42					Dundee	Dev	L	Por	15	A	1	Dundee	3,885
15	x	x	x			42.4	0.52		1,044	y	Monroe	Dev	L	Por	5	A	27	Monroe	3,318
16	x	x	x	y	y	43	25	P			Berea	Mis	S	Por	6	A	2	Dundee	2,733
17	515	x	515						1,060	y	Stray-Marshall	Mis	S	Por	10	A	5	Monroe	3,529
18																			
19																			

County, which reached the Trenton limestone and went to a total depth of 6674 ft. This is the deepest hole in the state.

Miscellaneous

On Jan. 1, 1935, the price of Michigan crude oil was $1.02, at which price it had stood since 1933. On Nov. 7, there was an increase to $1.12, and on Dec. 15 another increase to $1.22. On Jan. 1, 1936, it was again raised, to $1.32.

Proration in Michigan during the year was based on flat allowable plus a certain percentage of potential in order to make the state total fall within limits set by the Federal board. This was in effect only during the period of NRA operation. The Crystal field was not under proration to any extent, although there has been some restriction of production in that area in order to reduce salt-water encroachment.

The Crystal field, which is an area of small lakes with summer resort business, has a particularly difficult problem in connection with the disposal of salt water. Experiments are now being made to determine whether or not this water can be returned to some porous zone in the Monroe formation by pumping. In the Porter field the brine produced from the Dundee formation is carried by pipe line to the Dow chemical plant at Midland, Mich., where it is used for the extraction of chemicals associated with the salt.

Treatment with acid was standard practice in the fields of Michigan during the year.

During 1935 a number of new pipe lines were completed in Michigan, the most important being the Simrall and Standard Oil line, 142 miles, 8 in. in diameter, from Crystal field to Toledo, Ohio.

TABLE 2.—*Summary of Drilling Operations in Michigan during 1935*

Important Wildcats Drilled in 1935

County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
	Section	Township, Lat.	Range, Long.			
1 Gratiot	4	10 N.	4 W.	3536	Pleistocene	Dundee
2 Gratiot	29	10 N.	3 W.	4159	Pleistocene	Sylvania
3 Isabella	31	16 N.	4 W.	1504	Pleistocene	Stray
4 Livingston	35	3 N.	4 E.	5960	Pleistocene	St. Peter
5 Mecosta	22	13 N.	10 W.	1228	Pleistocene	Marshall
6 Midland	32	15 N.	2 E.	2495	Pleistocene	Berea
7 Montcalm	11	10 N.	5 W.	3198	Pleistocene	Monroe
8 Montcalm	1	9 N.	6 W.	3111	Pleistocene	Monroe
9 Montcalm	36	11 N.	5 W.	1032	Pleistocene	Stray
10 Montcalm	17	12 N.	9 W.	3374	Pleistocene	Monroe
11 Newaygo	12	13 N.	13 W.	6674	Pleistocene	Trenton
12 Ogemaw	31	21 N.	4 E.	2643	Pleistocene	Dundee
13 Saginaw	31	12 N.	2 E.	2749 (Now DD)	Pleistocene	Traverse
14 Wexford	13	22 N.	9 W.	3864	Pleistocene	Dundee

Michigan has 26 refineries, many of them built during the past year as a result of the rapid development of the Crystal field.

Acknowledgments

Mr. Lynn K. Lee, Division Geologist, The Pure Oil Co. at Saginaw, Mich., and George H. Bell, Chief Scout of the same company, assisted in the preparation of this report. Mr. Gerald Eddy and Mr. F. R. Fry, of the Michigan State Geological Survey, furnished production data on oil and gas and other information.

Table 2.—(*Continued*)

Important Wildcats Drilled in 1935

Drilled by	Initial Production per Day		Pressure, Lb. per Sq. In.		Remarks
	Oil, U.S. Bbl.	Gas, Millions Cu. Ft.	Casing	Tubing	
1 Crystal Oil & Gas	0	5	x	x	Gas from Stray
2 Newark Gas & Oil	0	0			Dry hole
3 W. Hunter Atha	0	3	y	y	First well in new gas area.
4 Talbot Oil Co.	0	⅙	x	x	Gas from Salina.
5 Jasmid Oil Corp.	0	1½	x	x	Gas from Stray.
6 K. K. Leibrand Tr.	32	0	y	y	
7 J. W. Leonard et al.	5000	x	x		Discovery well Crystal field.
8 Jetter & Lima Oil Corp.	25	x	x	y	Vickerville.
9 St. Louis Pipe & Suppy Co.	0	2	510y	y	Crystal gas.
10 L. G. Thompson et al.	0	6			Winfield gas.
11 Newaygo Oil & Gas Co.					Deepest well in state.
12 Thompson Bros. Inc.	50	0	y	y	Possible extension to Ogemaw.
13 King Drilling Co.	45	0	x	x	
14 M. J. Ingold	?	0	x	x	Made small amount oil from Traverse.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	80	28
Number of oil wells completed during 1935	307	4
Number of gas wells completed during 1935	93	8
Number of dry holes completed during 1935	84	129

Oil and Gas Development in Mississippi

By Henry N. Toler*

(New York Meeting, February, 1936)

Development in the Jackson gas field, Hinds and Rankin counties, for 1935 continued at a slow pace, there being only nine wells drilled on the structure, of which five resulted in gas producers and four in dry holes. There were no wells drilled deep enough during 1935 to test any of the horizons below the producing Selma chalk. There are 113 producing gas wells in the Jackson gas field, with three wells on the southeast edge of the field making some oil with a large quantity of salt water; this oil comes from the same horizon as the gas. The combined open flow of the 113 gas wells is about 4,100,000,000 cu. ft. The proven area of the field is approximately 8000 acres. The production of 10,291,000,000 cu. ft. for 1935 represents the largest yearly pull from the field by almost a billion cubic feet. The total production from the field to date is 45,104,000,000 cu. ft. It is interesting to note that the rock pressure has dropped from 1010 lb. per sq. in. initial to 943 lb. at the end of 1935, a decline of only 67 lb. in 6 years.

There is a difference of opinion as to the age of the deepest formation tested on the Jackson structure; some people holding that it is Tuscaloosa, others, Trinity, and still others that it is Paleozoic, probably Pottsville.

The production of the Amory gas field, Monroe County, continued to decline and the capacity was far under the demand. Originally there were four producing wells in the field with a combined open-flow capacity of approximately 15,000,000 cu. ft. and a rock pressure of 680 lb. per sq. in. At the end of 1935 only two wells were producing with a combined open-flow of less than 1 million cu. ft. and the rock pressure down to 100 lb. or less. No attempt has been made to drill new wells in the immediate field but three wells are being drilled in the county in an effort to secure new supplies of gas.

The wildcat operations for 1935, with only 11 wells drilled, were the lowest since 1932, just about one-half the number drilled during 1934. None of the wildcat wells drilled in 1935 resulted in producers and, so far as the writer is aware, did not uncover any large structures. The 11 wells drilled were abandoned or junked at comparatively shallow depths, except the well drilled in George County to 6928 ft. by the United Gas

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* State Oil and Gas Supervisor, Jackson, Miss.

Public Service Co. and a well drilled in Stone County to 7443 ft. by the Gulf Refining Co. Although these wells seemed to be regionally high, no important shows of oil or gas were reported.

There are 10 wildcat wells drilling or temporarily shut down in the state, in the following counties: Bolivar, Claiborne, Harrison, Lafayette, Lauderdale, Monroe, Warren, Washington and Winston.

TABLE 1.—*Oil and Gas Production in Mississippi in* 1935

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres			Total Oil Production, Bbl.				Average Oil Production, Bbl.		
			Oil	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily During Nov., 1935
1	Amory, *Monroe*	10	0	640								
2	Jackson, *Hinds and Rankin*	6	100	8,000	8,100	13,444	1,700	2,240	6	134		2+

Line Number	Total Gas Production, Millions, Cu. Ft.				Number of Oil and/or Gas Wells							Average Depth, Ft.		Oil Production at End of 1935		Pressure, Lb. per Sq. In.[e]		
						During 1935		At End of 1935						Number of Wells			Average at End of	
	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Pumping	Gas-lift	Initial	1934	1935
1	1,650	164	94	½	4	0	0	2		2	2	2,402	2,393			680	180	100
2	45,104	9,006	10,291	42	136	5	4		3	113	116	2,434	2,426	1	2	1,010	960	943

Line Number	Character of Oil, Approx. Average during 1935					Character of Gas, Approx. Average during 1935	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935	
	Gravity A.P.I. at 60° F.														
	Maximum	Minimum	Weighted Average	Sulfur Per Cent	Base[f]	B.t.u. per Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1						1,000	Hartselle	Mis	S	10	8	MU	2	Fort Payne	3,045
2	14	14	14	1.8	A	945	Selma	CreU	C	30	10+	D	50	Trinity or Pottsville	4,267

[b] Footnotes to column heads and explanation of symbols are given on page 215.

Leasing was carried on in many sections, the greatest interest and activity being shown in south Mississippi, where several of the major companies have extensive lease holdings. Several million acres are under lease in the state, some of it being blocks on which wells are to be drilled within the next year or two.

In Lamar County the Sun Oil Co. core-drilled a large block of acreage around a well drilled in sec. 21-4N.-15W. in 1934 to 3520 ft. This well apparently checked very high and it is thought that one or more wells will be drilled in this general area during 1936 or 1937. In Jefferson Davis and Lamar counties the Humble Oil and Refining Co. core-drilled two areas in which highs had been reported by seismograph work. Probably one or more wells will be drilled in Jefferson Davis County this year as a result of this work.

Geophysical work was done by several companies in south Mississippi during 1935, but the result of this work is not yet known, although it seems from reports that additional wells will be drilled in some of the areas where geophysical work was carried on. Wilkinson County, in the southwest corner of the state, has received considerable activity in geophysical work and leasing and it is reported that three wells will be drilled in this county during 1936.

TABLE 2.—*Summary of Drilling Operations in Mississippi*

Important Wildcats Drilled in 1935

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
		Section	Township, Lat.	Range, Long.					
1	Forrest	11	1 N.	13 W.	3007	Pascagoula	Claiborne	Gulf Rfg. Co. of La.	Dry.
2	Franklin	31	6 N.	2 E.	4024	Hattiesburg	Claiborne	F. E. Courson et al.	Dry.
3	George	10	2 S.	9 W.	3450	Pascagoula	Claiborne	Gulf Rfg. Co. of La.	Dry. Might have reached Wilcox.
4	George	6	1 S.	5 W.	6928	Pascagoula	Eutaw	United Gas P.S. Co.	Dry.
5	Grenada	19	22 N.	5 E.	4600	Wilcox	Pennsylvanian	W. L. Stewart et al.	Dry.
6	Harrison	22	6 S.	13 W.	4156	Pascagoula	Claiborne	Gulf Rfg. Co. of La.	Dry.
7	Issaquena	11	12 N.	8 W.	3227	Yegua	Trinity or Tuscaloosa	Pelican Oil & Gasoline Co.	Dry.
8	Jones	30	7 N.	12 W.	4300	Hattiesburg	Wilcox	Snow-Black Pet. Co.	Dry.
9	Simpson	33	2 N.	4 E.	2600	Catahoula	Claiborne	Berry Corp.	Dry; show of oil.
10	Stone	36	3 S.	11 W.	7443	Pascagoula	Eutaw	Gulf Rfg. Co.	Dry.
11	Warren	14	14 N.	1 E.	3252	Vicksburg	Wilcox	Harry W. Elliot et al.	Dry; show of gas.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	1	10
Number of oil wells completed during 1935	1	0
Number of gas wells completed during 1935	5	0
Number of dry holes completed during 1935	4	11

Oil and Gas in Missouri in 1935*

By Frank C. Greene,† Member A.I.M.E.

(New York Meeting, February, 1936)

Drilling for oil and gas in Missouri in 1935 was mostly confined to proven areas, but was marked by the completion of one of the largest oil wells, 53 bbl., and one of the largest gas wells, 2,000,000 cu. ft., drilled in recent years. A new oil pool, discovered in southern Cass County late in 1934, was further developed; a new pool in southern Platte County is possibly indicated by the completion of a single small well, which flowed naturally; and a deeper sand was developed in the Marota gas pool in Jackson County.

Completions dropped to a lower level than in any recent year. A total of 73 wells, which included the deepening of 8 old wells, was drilled. In Bates County, there was one gas well with an open flow of 100,000 cu. ft., and one dry hole. Cass County had six oil wells with about 100 bbl. initial production; one gas well with an open flow of 500,000 cu. ft., and three dry holes. In Jackson County there were seven oil wells with 25 bbl. initial production; 24 gas wells with 7,358,968 cu. ft. open flow, and 27 dry holes. Platte County had one oil well, one small gas well and one dry hole. The oil well flowed naturally about 4 or 5 bbl. per day.

It is rather difficult to obtain production figures on either oil or gas leases, but in cases where the figures have been given to the writer in confidence, they disclose conditions comparable with many other regions. One oil lease of 32 acres has produced 125,000 bbl. in four years, or nearly 4000 bbl. per acre. Another lease has made 50,000 bbl., or about 3000 bbl. per acre.

It is probable that the total daily production at the end of 1935 was close to 200 bbl. per day.

A gas pool covering less than one square mile has made 110,111,000 cu. ft. in about 18 months. In this period, the open-flow capacity has been reduced from about 10,500,000 cu. ft. per day to about 3,500,000.

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Petroleum and Natural Gas Development in Montana for 1935

By Eugene S. Perry*

(New York Meeting, February, 1936)

The only outstanding development in Montana oil or gas fields during 1935 was the extension of the Cut Bank oil and gas field 7 miles southward. This field is now about 20 miles long and 3 to 8 miles wide, with 218 producing oil wells and 39 producing gas wells. Average daily production of the oil field during December, 1935, was about 6700 bbl.; total production for the year 1935 was approximately 2,020,770 barrels.

The Cut Bank field in northern Montana is in a flat to rolling glaciated area used mainly for grazing purposes. Oil and gas occurs in sandstones and shaly sandstones in the Kootenai (Dakota) formation of Lower Cretaceous age at depths ranging from 2700 to 3000 ft. Prominent anticlinal or domal structure is not present, but small plunging anticlines occur locally. Strata dip westward from 75 to 200 ft. per mile. The field lies on the western flank of the Sweetgrass arch, a broad gentle upwarp over 150 miles long. Localization of oil and gas appears to be due either to pinching or lensing out of the sandstone beds, or else silting of the sandstones with clay minerals so that porosity becomes low. Within the field offset wells show marked variation in initial production, which suggests that differences in porosity of sandstone is the controlling factor. The gas-producing portion of the field is entirely updip (east) from the oil-producing portion, and the producing horizons are the same. Initial production of oil wells ranged from about 50 to about 200 bbl. per day, and initial open flow of gas wells ranged from about one million to about 37 million cubic feet per day, with an average of 11 million cubic feet. Initial gas pressures were slightly greater than 700 lb. per sq. in. Oil is brought to the surface by pumping. Both rotary and standard churn-drilling equipment are used.

In the remaining 14 oil and gas fields but little new activity took place other than the drilling of offset wells and wells in proven territory. Continuation of "acid treatment" of wells in the Kevin and Pondera oil fields led to reconditioning of many old wells and the drilling of a number of new wells within these fields. Acid treatment of the oil-bearing horizon, which is the dolomitized and silicified Madison limestone of Mississippian age, has proved quite satisfactory, and some "bone dry"

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TABLE 1.—*Oil and Gas Production in Montana in* 1935

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.				Average Oil Production, Bbl.	
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935
1	Baker-Glendive, *Fallon, Dawson, Wibaux*	21			50,000	50,000						
2	Bowdoin-Saco, *Phillips*	19			50,000	50,000						
3	Elk Basin, *Carbon*	19	160			160	753,000	16,063	8,218		*y*	
4	Cat Creek, *Petroleum, Garfield*	15	1,000			1,000	13,825,000	236,018	292,750	781	*y*	4.1
5	Soap Creek, *Big Horn*	15	160			160	small				*y*	
6	Kevin-Sunburst, *Toole*	13	45,000		50,000	95,000	30,510,000	1,628,509	1,360,964	4,962	*x*	4.9
7	Whitlash, *Toole, Liberty*	11	500	500	4,000	4,500	small				*y*	
8	Bannatyne, *Teton*	9	700			700	77,000	1,494	Abd.		*y*	
9	Bowes, *Blaine*	9			*y*1,500	*y*1,500						
10	Cut Bank, *Glacier*	9	25,000		32,000	57,000	3,815,000	1,204,226	2,323,141	5,534	*x*	23.8
11	Lake Basin, *Stillwater*	8	100	100	1,000	1,000	334,000	?	18,055	48	*y*	9.8
12	Dry Creek, *Carbon*	8		2,000		2,000	738,000	11,545	60,421	156	*x*	19.5
13	Pondera, *Pondera, Teton*		4,500			4,500	4,009,000	362,585	431,233	1,148	*y*	7.3
14	Hardin, *Big Horn*	6			5,000	5,000						
15	Border or Red Coulee, *Toole*	5	260			260	606,000	69,913	64,882	249	*y*	10.8
16	Box Elder, *Hill*	4			*y*1,000	*y*1,000						
17	Devils Basin, *Musselshell*	16	200			200	5,000	(Field shut in, 1925)				

[a] Footnotes to column heads and explanation of symbols are given on page 215.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production: Production in 1934, Cu. Ft.	Number of Oil and/or Gas Wells: Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Producing Gas Only	At End of 1935: Total Producing	Depth, Average Ft.: Bottoms of Productive Wells	Depth, Average Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Flowing	Oil Production Methods at End of 1935, Number of Wells: Pumping	Pressure, Lb. per Sq. In.[a]: Initial	Pressure: Average at End of 1934	Pressure: Average at End of 1935	Character of Oil, Approx. Average during 1935: Gravity A.P.I. at 60° F.: Maximum	Gravity: Minimum	Gravity: Weighted Average	Sulfur, Per Cent	Base[f]
1	6,014,680,000	200	1		66		88	88	950	700 1,350			210 to 430	90	90					
2	417,050,000	28	2		2		24	24	850	700 800 880			210 435	y	y					
3		30	y	y	y	y		y	2,400	2,400		y (all)	1,400±	y	600	y	y	40		P
4		288	3	y	y	190		190	1,350	1,300 1,500		190	y	y	(low) y	50	47	48	0.3	M
5		12		y	y	5		5	1,640	y1,600		5	y	y	y	y	y	19		M
6	2,046,208,000	2,148	52	y	y	1,019	161	1,180	1,400	1,200 1,400		1,019	360	300	y	34	27	32	1.37	M
7	447,357,000	28	2	y	3	6	6	12	1,900	y1,900		6	275 to 368	y	260	y	y	38	0.0	P
8		49		y	y	[1]		[1]	1,500	1,500		[1]	y (low)	y	y low	27	23	25		A
9	433,446,000	7	·				7	7	900	900			250	225	y					M
10	5,049,666,000	307	124	y	y	232	39	271	2,840	2,830		232	720	700	y	y	y	36		Mainly P
11	gas shut down	40		y	12	5	[2]	5	1,500	1,200 3,000		5	y	y	250	y	y	46		P
12	200,000??	20	1	y	y	8	4	12	4,400	2,350 4,450 5,400	8		1,400±	y	1,250	y	y	52		P
13		178	3	y	y	157		157	2,050	2,045		157	500	y	y (low)	y	y	33	y 1.00	M
14		20	1	y	y		20	20	775	775			137	y	y (low)					
15		31		y	y	23	1	24	2,475	2,430		23	390	y	y (low)	y	y	31		M
16	412,206	2	1				2	2	1,270	y1,270			430	300	y			26		A
17		42			5				1,175	1,167		5 (shut in)								

[1] Field shut down 1935.
[2] Gas shut down.

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Character of Gas: Gal. Gasoline per M Cu. Ft.	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Porosity[i]	Producing Rock: Net Thickness, Average Ft.	Producing Rock: Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Deepest Zone Tested: Depth of Hole, Ft.
1	1,015	0.00	(Two horizons)	CreU	SH	15	55	A	46	Chugwater (Triassic)	5,848
			Pierre (Mont. Group)								
			Judith Riv., Eagle			10	50				
2	989	0.00	Colorado (Three stray sands)	CreU	SH	12–18	50	Dou-	*y*	Upper Carboniferous	3,180
							50	ble			
							50	D			
3	1,105	0.00	Wall Creek (Frontier)	CreU	S		30–70				
			Dakota	CreL	S	5–10	25	DF	*y*	Dakota (CreL)	*y*
4			Colorado (Basal SS)	CreU	SH	15	40				
			Kootenai (2d Cat Creek)	CreL	S	20	40	DF	95	Madison (Mississippian)	2,086
5			Quadrant (Tensleep sand)	Pen	S	5–12	*y*	D	*y*	Upper Paleozoic	*y*
6	1,040	*y*0.0	Kootenai (Gas) (Sunburst)	CreL	S	12	20				
			Madison (Oil)	Mis	L[3]	*x*	*x*	MC	698	Pre-Cambrian	4,520
7	1,070	*y*	Colorado (Black Leaf sand)	CreU	S	12–18	35	D	11	Madison (Mississippian)	2,560
8			Ellis (Emerick sand)	Jur	S	7–12	50	D	14	Madison (Mississippian)	1,905
9	985	0.00	Eagle	CreU	SH	20	78	DF	0	(Devonian?)	4,700
10	1,011	0.0	Kootenai	CreU	S	18	30	MC	*y*24	Madison (Mississippian)	3,010
	1,011		Eagle } Montana group								
11	to		Telegraph }		S						
					SH						
	1,053	0.00	Frontier } Colorado group	CreU	H	10–20	65	D	11	Dakota (Lower Cretaceous)	3,930
			Cloverly (Dakota)								
12	1,100	0.00	Eagle } Montana group			10–20	30				
			Frontier 1st sand } Colorado group	CreU	S	7–12	30–75	DF	*y*	Tensleep (Pen)	6,887
			Frontier 2nd sand								
			Cloverly	CreL	S		15	DF;			
13			Madison	Mis	L[3]	*x*	*x*	Nose	16	Madison (Mississippian)	2,354
14	1,040	0.00	Colorado	CreU	SH	10–15	20	MC Nose	0	Colorado (Upper Cretaceous)	2,800
15	*y*	*y*	Cosmos (Basal Kootenai)	CreL	S	10–15	35	MC Nose	7	Madison (Mississippian)	2,690
16	1,037	0.00	Eagle	CreU	SH	20	70	D	0	Eagle (Cretaceous)	1,320
17			Big Snowy	Mis	S		9	D	37	Madison (Mississippian)	1,900

[3] Altered limestone, dolomitized and silicified; somewhat cavernous. Porosity sometimes up to 50 per cent.

wells have been converted into good producers. Oil production for 1935 for the Kevin field amounted to about 1,298,500 barrels.

A deep test well (5848 ft., December, 1935), located by geophysical methods in the Baker gas field, found water in the Dakota sandstone, which is about 5000 ft. beneath the gas-producing horizon. Production of gas continued from the Judith River shaly sandstone at a depth of about 750 ft. The field is 75 miles long, 1 to 3 miles wide, and has 88 producing wells.

Oil fields in Montana in which some activity has taken place or in which production has continued are as follows: Cut Bank, Kevin-Sunburst, Border, Pondera, Dry Creek, Cat Creek, Sweetgrass Hills and Lake Basin; gas fields are: Cut Bank, Kevin-Sunburst, Boxelder, Bowes, Bowdoin-Saco, Sweetgrass Hills, Dry Creek, Baker-Glendive and Hardin.

In the year 1935 Montana had about 1600 producing oil wells in eight active oil fields. The average yield per well per day was about 10 bbl. of oil. About 350 gas wells were producing in nine separate gas fields. Statistical information on all fields is given in the accompanying tables.

Table 2.—*Summary of Drilling Operations in Montana in 1935*

Important Wildcats Drilled in 1935

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day	Remarks
		Section	Township, Lat.	Range, Long.					Oil, U.S. Bbl.	
1	Fallon....	17	4 N.	62 E.	5848	Pierre (Bearpaw)	Chugwater	Montana-Dakota-Utilities	Dry	Water in Dakota sand.
2	Glacier...		32 & 33 N.	5 W.	2950	Two Medicine	Kootenai	25 wells by several companies	Average 100 bbl. per well	Extended Cut Bank field 7 miles southward.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935..............................	*y*	*y*
Number of oil wells completed during 1935..........................	180	*y*
Number of gas wells completed during 1935.........................	9	*y*
Number of dry holes completed during 1935..........................	25	*y*

Oil and Gas Development in New Mexico

By E. H. Wells,* Member A.I.M.E., and A. Andreas†

(New York Meeting, February, 1936)

The oil and gas industry of New Mexico recorded notable progress in 1935. More wells were brought in than in any previous year, and important new discoveries were made. The total number of completions was 340, of which 260 were oil wells, 8 were gas wells and 72 were dry holes. The total oil production was 20,228,947 bbl., an appreciable increase over the 1934 production of 16,636,804 barrels.

Many of the wells completed in southeastern New Mexico were acidized. This treatment proved highly effective in increasing the capacity of the wells, the resulting potentials usually being two to ten times as large as before acid treatment. In the Lea County fields in which proration was entirely on an acreage basis, the tendency of many of the operators was to complete their wells according to best conservation practice rather than to obtain the largest possible potential.

Much remedial work was done in the Hobbs, Cooper, Jal and Eunice fields, and with excellent results. At many of the wells high gas-oil ratios were greatly reduced and encroaching waters shut off by setting packers.

Several companies carried on pretentious geophysical campaigns in the southeastern part of the state. The location of the Amerada discovery well in the Monument field was based on geophysical surveys.

The New Mexico Oil Conservation Commission, established by the 1935 Legislature and consisting of the Governor, the Commissioner of Public Lands and the State Geologist, began to function in May. Production in the state thereafter was based on orders issued by the Commission. Proration in the Hobbs field, which had been provided for since July, 1930, by successive proration agreements signed by all operators in the field and approved by the State Geologist, was continued by the Commission by giving approval to the current proration agreement. A plan of proration for the other Lea County fields that had been in effect since early in 1934 was adopted. In September, 1935, the Commission approved a proration agreement for the Artesia-Jackson-Maljamar area in Eddy and Lea counties that had been agreed upon by

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the operators in the area. In San Juan County, where the Rattlesnake, Hogback and Table Mesa fields are each operated by a single company, the Commission allocated oil to the fields as a whole instead of on a per well basis.

Southeastern New Mexico

Hobbs Field.—Developments in this field consisted chiefly of drilling in extensions of the field to the northwest, northeast and east. There were 34 completions with an aggregate potential of 305,320 bbl. The potential of the Hobbs field at the beginning of the year was 2,168,278 bbl., and at the end of the year was 2,216,807 bbl. The increase was considerably less than the potential of the wells brought in during the year because of decreased potentials of the older wells.

In 1935 the Hobbs field produced 11,068,664 bbl. of oil. The daily allowable for Jan. 1 to 15 was 33,476 bbl., and for Dec. 16 to 31 was 27,555 bbl. Although the daily production decreased markedly during the year, because the increase in the state allowable did not keep pace with the new completions, the field continued to be the largest producer in New Mexico.

Eunice Area.—The Eunice area, which includes the North Eunice field and the South Eunice field, was the most active in the state in 1935. Ninety-two wells were drilled, of which 91 were classed as oil wells and one as a dry hole. Most of the development in the area was done in the North Eunice field, which was extended in all directions without reaching the limits of production. The field probably connects with the Monu-

Table 1.—*Oil and Gas Production in New Mexico*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
1	Hogback, *San Juan*	13	160	0	0	160	1,656,772	73,286	68,816	182
2	Artesia (Jackson, Maljamar, Getty), *Eddy*	12	10,660		2,840	13,500	6,922,959	859,756	844,443	2,363
3	Rattlesnake, *San Juan*	11	640	0	0	640	3,249,306	268,658	260,111	853
4	Aztec-Bloomfield, *San Juan*	11	90		5	95	24,166	5,503	4,166	9
5	Table Mesa, *San Juan*	10	100	0	0	100	395,362	23,892	34,413	75
6	Hospah, *McKinley*	8	50	0	0	50	0	0	0	0
7	Jal, *Lea*	8	1,880	200	360	2,440	4,333,894	1,020,123	1,405,161	3,612
8	Eunice, *Lea*	7	5,200		80	5,280	5,219,389	978,444	3,314,720	12,144
9	Hobbs, *Lea*	7	1,200	8,240		9,440	64,527,283	12,466,991	11,068,664	28,546
10	Cooper, *Lea*	6	3,520			3,520	3,100,505	322,686	2,531,852	8,694
11	Lea and Lea Ext., *Lea*	6	520			520	5,573,368	617,465	459,207	1,011
12	Monument, *Lea*	1	1,120			1,120	237,394		237,394	1,635
13	Total						95,240,398	16,636,804	20,228,947	

[a] Footnotes to column heads and explanation of symbols are given on page 215.

ment field about 5 miles north, and with the South Eunice field 1½ miles to the south.

In the South Eunice field the Ohio Oil Co. completed its State-McDonald No. 3 well in sec. 16, T.22S., R.36E. on June 6, 1935, at a depth of 3816 ft., with an initial production of 6000 bbl. Several additional wells were drilled in the field.

The Eunice area was the most active in the state at the close of the year, when 21 wells were drilling. Many additional wells will be drilled in 1936.

Cooper Field.—The developments in the Cooper field, which were all of a routine nature, extended the field to the north and south. A large increase in the amount of water to be handled became a serious problem for the operators.

Jal Field.—Completions were scattered throughout the field, and none of the new wells had a notably large initial production. Gas wells in the southern part of the Jal field continued to supply the pipe line of the El Paso Natural Gas Co., which furnished gas to El Paso, Texas, and points in southern New Mexico, Arizona, and Sonora, Mexico.

Monument Field.—The discovery of this field dwarfed all other developments in the state for 1935. The discovery well of the Amerada Petroleum Corporation, State D-1 in sec. 1, T.20S., R.36E., was completed March 16. The well was drilled into sulfur water at 3952 to 3954 ft., then plugged back and completed at 3945 ft. Its potential after treatment with acid was 3552 bbl. of oil and 2,100,000 cu. ft. of gas.

A large-scale drilling campaign began immediately after the discovery well was brought in. By the end of the year 28 wells had been completed,

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
								During 1935		At End of 1935				
	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	10,355	26	0	0	0	0	7	0	0	0	7	0	0	7
2	649	11.2	x	x	x	x	354	11	19	11	216	y	y	216
3	5,077	28	0	0	0	0	34	7	2	2	30	0	0	30
4	268	3	20y	1.5x	1.5x		27	3	y	7	18	0	2	20
5	3,954	12	0	0	0	0	6	0	0	0	6	0	0	6
6	0	0	0	0	0	0	3	0	0	0	0	0	0	0
7	2,084	77	x	x	12,016x	x	68	23	5	2	49	5	9	63
8	1,004	119	x	x	9,197x	x	137	92			130		2	132
9	6,835	116	97,630	16,585	15,439x		251	34		1	44	206		250
10	881	104	x	x	6,789x	x	95	62		2	86		4	90
11	12,667	79	x	x	x	x	35	0			13			13
12	212	117	x		244x	x	28	28			28			28
13					43,685x		1,045	260	26	25	627	211	17	855

all of which were productive, and all but one of which flowed naturally. On Jan. 1, 1936, 17 wells were drilling. The most spectacular was the Barnsdall Oil Corp. Cooper No. 1 in sec. 12, T.20S., R.36E., completed at 3890 ft. with a rated daily potential of 28,272 bbl. following several treatments with acid, which is the largest well ever completed in New Mexico.

The producing zone of the Monument field is the Permian "White lime," the producing formation of the other Lea County fields. The gravity of the oil is approximately 34° A.P.I., or about the same as the gravity of the oil at Hobbs.

The development of the field at the end of the year was in two separate areas, the larger of which surrounded the Amerada discovery well; the smaller area was about 2 miles northeast, in secs. 13 and 24, T.19S., R.36E., and secs. 18 and 19, T.19S., R.37E.

Bearing in mind that no dry holes were drilled in this area in 1935, it is logical to expect that the two separate productive areas are parts of a single pool. In all probability the field connects with the Eunice field to the south. It should eventually rival the Eunice field, and possibly the Hobbs field, in size and production.

Artesia-Jackson-Maljamar Area.—More drilling was done in this area than for several years, and most of the oil wells brought in were in T.17S., R.28E. north of the old Artesia field, and in the Jackson-Grayburg field in T.17S., R.30E. Maljamar Oil & Gas Corporation's Baish No. 5 in sec. 21, T.17S., R.32E., Maljamar field, was completed as a 90-bbl. well in a sand zone at 2362 to 2371 ft. The main producing horizon of the field is approximately 4100 ft. deep.

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Flowing	Pumping	Gas-lift	Air-lift	Pressure, Lb. per Sq. In.[a]: Initial	Average at End of 1934	Average at End of 1935	Character of Oil, Approx. Average during 1935, Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	714	705	7	0	0	0	x	x	x	60	60	60	0.08	P
2	2,251		12	197	0	7	x	x	x	39.6	35	37.1	0.87	M
3	808	784	6y	24y	0	0	y	y	y	87	60	60	0.05	P
4	1,075	750	0	18	0	0	0	0	0	58	50	55	0.08	P
5	1,337	1,325	0	6	0	0	0	0	0	57	56	56.5	0.04	P
6	1,651	1,640	0	0	0	0	x	x	x	y	y	29.7	0.15	M
7	3,333		41	12	1		x	x	x			28.5	1.97	P
8	3,859		125y	5y					1,332y	35	32	33.5	1.65	P
9	4,173	4,049.6	238	12			1,525	1,328	x	35.5	35	35.3	1.47	M
10	3,564		70	7	9		x	x	x			29	y	P
11	3,771			13			x	0	0			27	1.53	P
12	3,945		27	1	0	0	1,427		1,418y			34	y	P
13			526	295	10	7								

Gas from wells in this area was utilized in Roswell, Artesia, Carlsbad and other Pecos Valley towns.

Considerable drilling in the more promising proven parts of the area should take place in 1936.

Wildcat Operations.—In the southeastern part of the State 41 wildcat wells were drilled, 18 of which were in Lea County. Two of the Lea County tests encountered commercial amounts of oil, and one not completed at the end of the year was evidently a commercial well.

The Amon G. Carter Mattix No. 1 in sec. 3, T.24S., R.37E., was completed at 3915 ft. with an initial production of 160 bbl. and an estimated 1,000,000 cu. ft. of gas. This well is 5½ miles east of the producing wells in the Cooper area.

The Harrison No. 1 well of the Skelly Oil Co. in sec. 5, T.23S., R.37E., was brought in with a potential of 120 bbl. and 200,000 cu. ft. of gas. The nearest producing field was the South Eunice field about 5½ miles northwest.

The Penrose-Rowen Drilling Co. apparently opened another pool with its Carey No. 1 in sec. 22, T.22S., R.37E., about 5 miles east of the South Eunice field. At the end of the year the well was 3555 ft. deep and was flowing by heads. Its potential was estimated at better than 100 barrels.

The Mattix and Harrison wells obtained production in a sandy lime just above the "White lime" of the other Lea County fields, but the Carey well was producing from a sand horizon several hundred feet above the "White lime."

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1935		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1933	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1			Dakota Ss	CreU	S	*y*	9	D	9	McElmo-CreL	1,225
2	*y*	*y*	Upper San Andreas	Per	D	*y*		AM	106	Pennsylvanian?	6,683
3			Dakota Ss	CreU	S	*y*	24	Af	16	Magdalena-Pen	6,771
4	1,153		Farmington Ss	CreU	S	*y*		S	54	Lewis shale, CreU	2,665
5			Dakota Ss	CreU	S	*y*	5	A	7	Chinlee-TriasU	3,010
6			Mesa Verde	CreU	S	*y*	11	DF	12	Mancos-CreL	3,282
7	*y*	*y*	White lime	Per	D	Cav		A	8	San Andreas-Per	4,125
8	*y*	*y*	White lime	Per	D	Cav		A	3	San Andreas-Per	4,237
9	1,150	1.98	White lime	Per	D	Cav	123	A	9	San Andreas-Per	4,500
10	*y*	*y*	White lime	Per	D	Cav		A	3	Lower San Andreas-Per	5,095
11			White lime	Per	D	Cav		AM	16	San Andreas-Per	4,046
12	*y*	*y*	White lime	Per	D	Cav		*x*	0	San Andreas-Per	4,093
13									243		

Pipe Lines.—The Lea County fields were served by lines of the Shell, Texas, Humble and Atlantic pipe line companies, all of which transported the oil into Texas. New construction consisted of the extension of an 8-in. line by the Texas Pipe Line Co. from its trunk line near the North Eunice field to the Monument field. Late in the year the Shell Pipe Line Co. announced plans for constructing early in 1936 an additional trunk line from southern Lea County to Wink, Texas, which would greatly increase the capacity of its system in New Mexico. The Gulf Refining Co. completed plans for constructing an 8-in. pipe line from Winkler County, Texas, to the Monument and Hobbs fields.

Northwestern New Mexico

Only a small amount of development drilling took place in northwestern New Mexico, most of it in the Rattlesnake field. No important discoveries were made by wildcatting in this area.

Table 2.—*Summary of Drilling Operations in New Mexico in* 1935

Important Wildcats Drilled in 1935

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Section	Township, Lat.	Range, Long.					Oil, U.S. Bbl.	Gas, Millions Cu. Ft.	
1	Sandoval	2	13 N.	4 W.	6220	Mancos shale-Cre	Magdalena-Pen	Continental Oil			Abandoned in schist
2	Union	4	29 N.	29 E.	2800	Dakota Ss-Cre	Abo-Permian	Sierra Grande Oil			Abandoned in granite
3	Roosevelt	21	2 S.	30 E.	3659	Tertiary	Glorieta-Per	Arnold Syn. (Claudell)			Abandoned
4	Lea	8	20 S.	35 E.	4455	Quaternary	Permian	Anderson-Prichard			Abandoned
5	Lea	3	24 S.	37 E.	3940	Tertiary	Permian	Carter, Amon, G.	43	1.	
6	Lea	23	21 S.	32 E.	3602	Quaternary	Permian	Culberson-Irwin			Abandoned
7	Lea	10	21 S.	32 E.	3872	Quaternary	Permian	Culberson-Irwin			Abandoned
8	Lea	4	22 S.	34 E.	4140	Quaternary	Permian	Humble			Abandoned
9	Lea	27	25 S.	37 E.	3654	Tertiary	Permian	Jeffers			Abandoned
10	Lea	17	22 S.	37 E.	4077	Tertiary	Permian	Penrose and Rowan			Abandoned
11	Lea	11	20 S.	38 E.	4757	Tertiary	Permian	Repollo			Abandoned
12	Lea	35	20 S.	32 E.	3410	Quaternary	Permian	Ryan Consolidated			Abandoned
13	Lea	5	23 S.	37 E.	3781	Tertiary	Permian	Skelly	120	¼M	
14	Lea	35	19 S.	33 E.	4150	Quaternary	Permian	Texas			Abandoned
15	Lea	1	20 S.	36 E.	3954	Tertiary	Permian	Amerada	3552	2.1	
16	Lea	22	22 S.	37 E.	3555	Tertiary	Permian	Penrose and Rowan			Not completed in 1935, but making oil by heads

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	59	19
Number of oil wells completed during 1935	258	2
Number of gas wells completed during 1935	8	0
Number of dry holes completed during 1935	20	52

Northeastern New Mexico

The Witt Oil and Gas Co. completed a small well in its proven carbon dioxide gas field in the Estancia Valley, Torrance County, making a total of four producing wells with a combined capacity of approximately 1,000,000 cu. ft. of carbon dioxide gas. A small amount of "dry ice" was manufactured at the plant of the company at Witt and marketed. The few wildcat wells drilled in northeastern New Mexico in 1935 were all dry holes.

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Petroleum and Natural Gas in New York in 1935

By D. H. Newland,* Member A.I.M.E.

(New York Meeting, February, 1935)

New York has a small but not insignificant place in the oil and natural gas industries of the United States. It has had a continuous record as an oil producer since 1872, with an aggregate yield of about 104,000,000 bbl. The reported output for 1935 was 4,237,000 bbl., a gain of more than 10 per cent for the year and a total that has been exceeded only in the early period of flush production half a century ago. The industry has been steadily building up since 1920 with the successful practice of the water drive, which has given a new lease of life to pools that had been practically drained of oil recoverable by pumping. An additional output of 2000 bbl. or more per acre is being procured by this method. Altogether the fields in New York State cover about 55,000 acres. Their limits are well defined and it is unlikely that they will be extended in the future, although there is some prospect of finding additional supplies by deeper drilling. The oil from New York is all classed as Pennsylvania grade, for which the recent price has been about $2.50 a barrel. It is refined at Olean, Wellsville and Bolivar, in the oil district, and partly in Pennsylvania refineries.

Exploration for natural gas, outside of the established districts, was considerable during the year. Altogether 59 wells were drilled, distributed over 13 counties, of which 33 were listed as producers and 26 were dry. At the close of the year, 13 wells were in process of drilling. The 33 producing wells had a combined estimated flow of 278 million cubic feet per day. The best results were obtained from exploration in Allegany County, where out of eight wells drilled to the Oriskany sandstone five were successful and showed a combined open-flow capacity of 107 million cubic feet. The Oriskany sandstone was encountered at a depth of 4500 to 4900 ft. In Steuben County, next east of Allegany County, two out of seven wells to the Oriskany proved productive, and one of these, in the town of Greenwood, on the Watkins structure, was probably the largest that has so far been opened in the state, with a reported yield of 35 million a day. In the central part of New York interest was awakened by the activity shown in exploring for gas in the Trenton limestone, in Camden, Florence and Rome townships, Oneida

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County. Nineteen wells were drilled altogether, of which 13 were given as productive. The wells ranged from about 900 to 1600 ft. in depth, and the Trenton formation, including limestone and shale, was from 500 to 600 ft. thick. The gas came from various horizons in the Trenton, probably held in pockets and joints, since no evidence of structural control was found. In the older gas fields of southwestern and western New York, exploration was more or less at a standstill, because of the excess supplies of gas from the Tioga and Hebron fields, Pennsylvania which have been finding a market in those parts.

Oil and Gas Development in Ohio for 1935

By R. E. Lamborn,* Member A.I.M.E.

(New York Meeting, February, 1936)

A summary of oil and gas development in Ohio for 1935 must necessarily be brief. As attention of the state government to the oil and gas industry has never included the collection and compilation of statistics on production, either by producing sands, by counties, by fields, or for the state as a whole, such information as requested in Table 1 of this symposium is impossible to secure for this state. In the absence of production data chief attention must be directed to drilling activity for the year. Information such as can be compiled from various sources, including weekly drilling reports to operating companies and trade journals, is given in the following paragraphs with the realization that the data may not be complete in all its details.

Drilling Activity by Fields

Drilling activity during 1935 was similar to the preceding year in that the major operating companies were generally content to drill lease-requirement and offset wells and in that comparatively little effort was made to discover new pools. A compilation of completions recorded in weekly reports to drilling companies and in trade journals show 1022 tests completed for the year in 53 counties of the state. Of this total number, 653 wells were commercial producers and 369 were classed as dry holes. Production was secured in 40 counties from formations ranging in depth to 5700 ft. and ranging in age from Middle Ordovician to upper Pennsylvanian. From the standpoint of new production for the year, the most important sands are the Clinton of Silurian age, the Berea of Mississippian age and the Shallow sands of Mississippian above the Berea and of Pennsylvanian age.

Trenton Sand Field

Production in the field of Trenton sand, which originally included parts of 15 counties in northwestern Ohio, is now on the decline. Seventy-three completions were reported in this field during 1935, of which 33.8 per cent were dry holes. Activity centered in Allen County with 12 completions, two of which were dry holes; in Hardin County with 11 producers; and in Wyandot County with 12 producers and 2 dry holes.

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A well drilled to the Trenton sand in Marion township, Henry County, with an initial production of 50 bbl. of oil per day may lead to further drilling activity in that vicinity.

Further search for natural gas may occur in Logan County, where a well with an initial open flow of 110,000 cu. ft. was secured from the Trenton sand at a depth of 1318 feet.

Deep Tests below the Trenton Sand

Since commercial production from the Trenton sand began, about 1885, there has been a consistent effort to secure production at deeper stratigraphic horizons. Tests have been sunk, without encouraging results, to the pre-Cambrian crystallines near Woodville, Sandusky County; Tiffin, Seneca County; Findlay, Hancock County, and Waverly, Pike County. The horizon of the St. Peter sand is encountered at depths below the top of the Trenton limestone ranging from 450 to 850 ft. in the western half of Ohio. During the past 50 years, 100 tests (estimated) have been drilled to this horizon in at least 42 counties without profitable results. In Marion County, Claridon township, a well drilled to the St. Peter sand in 1935 proved to be a dry hole. Two deep tests now drilling, one in Orange township, Delaware County, and the other in Rice township, Sandusky County, have passed the St. Peter without encouraging results from that horizon.

Clinton Sand Field

The Clinton sand field, which extends from the Ohio River in Lawrence County to Lake Erie in Lorain, Cuyahoga and Ashtabula counties, continues to be an important source of oil and gas after nearly 50 years of active commercial production. During the year, 274 wells were sunk to the Clinton sand in 23 counties of the field. The sand was reached at depths ranging from 2300 ft. in Lorain County to about 5500 ft. in Harrison County. Of the 274 tests drilled, 30.6 per cent were dry holes while 69.4 per cent were commercial producers. Production of oil and/or gas was secured in 20 counties. Drilling was most active in Stark, Knox, Coshocton, Muskingum, Licking, Perry and Fairfield counties, where 95 producers were obtained from a total of 131 wells drilled. For the year the largest initial production, 300 bbl. of oil per day, was secured from a well drilled in Ward township, Hocking County, whereas the largest gas well having an initial open flow of 8,505,000 cu. ft. natural was drilled in Brush Creek township, Muskingum County.

An attempt to derive production from the Clinton sand in Portage County by drilling one test in Shalersville township and another in Paris township proved a failure; both holes were dry.

Two small gas wells in the Clinton sand in Tallmadge township, Summit County, may lead to further drilling in that vicinity.

Harrison County entered the list of Clinton producers when a well sunk in Franklin township secured gas at a depth of about 5560 feet.

Newburg Sand Field

The Newburg sand is relatively unimportant in Ohio, where production has been secured chiefly in Cuyahoga, Summit and Stark counties at depths ranging from 2200 to 4000 ft. Production was first obtained from the Newburg about 1911 in Cuyahoga County. Only five gas wells were secured in this sand in 1935.

Oriskany Sand Field

The chief field of the Oriskany sand is in Guernsey, eastern Muskingum, and Tuscarawas counties, where production is secured at depths ranging from 3000 to 3700 feet. Six completions in the Oriskany sand were reported in Guernsey County in 1935.

In Sugar Creek township, Stark County, an Oriskany sand well of 648,000 cu. ft. capacity, obtained at a depth of 2805 ft., may lead to further exploration in this locality.

In Columbiana County a deep well to the Oriskany sand in sec. 30, Madison township, yielded a volume of gas reported at 1,000,000 cu. ft. The sand, which was reached at a depth of 4543 ft., had a thickness in this well of 23 ft. The well is near the crest of one of the largest structures in eastern Ohio. A second well about 2 miles to the east, in which the sand was found 85 ft. lower structurally, yielded a show of gas and much salt water.

No sand was found at the Oriskany horizon in a deep test drilled in Brush Creek township, Jefferson County.

Devonian Shale Gas Field

The field of commercial production from the Devonian shale is in Lawrence and Scioto counties. Little development has occurred in this field during the year and no new pools of commercial importance have been discovered, although the Devonian shales continue to be a source of small gas wells for single house consumption.

Berea Sand Field

The Berea sand field includes a large part of the eastern half of Ohio and overlaps the Clinton, Newburg and Oriskany sand fields. Drilling to this sand has occurred since 1860 and innumerable pools have been discovered at depths ranging from 50 ft. near the outcrop to over 2000 ft. along the Ohio River in Monroe County. During 1935 a total of 382 wells were sunk to the Berea sand in 31 counties of the field. Production was secured in 27 counties. Of the total number of wells drilled, 144, or

about 37.7 per cent, were dry holes and 238, or 62.3 per cent, were producers. Drilling in this field was most active in Athens, Guernsey,

Summary of Drilling Operation in Ohio for 1935

(Figures in body of tabulation represent number of holes)

County	Dry and/or Near-dry Holes							Producing Wells						
	Depth, Ft.						Total	Depth, Ft.						Total
	0–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000		0–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	
Allen	0	2	0	0	0	0	2	0	10	0	0	0	0	10
Ashland	3	0	4	0	0	0	7	4	0	4	0	0	0	8
Athens	15	6	0	0	0	0	21	16	17	0	3	0	0	36
Auglaise	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Belmont	1	6	1	0	0	0	8	3	19	1	0	0	0	23
Carroll	0	6	0	0	0	0	6	0	2	0	0	0	0	2
Columbiana	14	0	0	0	1	0	15	11	0	0	0	1	0	12
Coshocton	1	0	0	0	0	0	1	5	1	9	0	0	0	15
Cuyahoga	0	0	1	1	0	0	2	0	0	3	0	0	0	3
Darke	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Fairfield	0	0	2	0	0	0	2	0	1	11	0	0	0	12
Gallia	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Guernsey	2	26	0	0	0	0	28	0	29	0	5	0	0	34
Hancock	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Hardin	0	0	0	0	0	0	0	0	11	0	0	0	0	11
Harrison	0	4	0	0	0	0	4	0	3	0	0	0	1	4
Henry	0	0	0	0	0	0	0	0	2	0	0	0	0	2
Hocking	0	2	1	0	0	0	3	1	0	0	6	0	0	7
Holmes	0	1	0	4	0	0	5	6	3	0	0	0	0	9
Jackson	0	0	0	0	0	0	0	0	5	0	0	0	0	5
Jefferson	0	3	0	0	0	0	3	0	4	0	0	0	0	4
Knox	4	0	12	7	0	0	23	7	0	9	11	0	0	27
Lawrence	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Licking	6	1	1	1	0	0	9	17	0	14	4	0	0	35
Logan	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Lorain	1	0	5	0	0	0	6	5	0	7	0	0	0	12
Mahoning	5	0	0	0	0	0	5	1	0	0	0	0	0	1
Marion	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Medina	21	0	0	10	0	0	31	32	0	4	5	0	0	41
Meigs	12	5	2	0	0	0	19	24	32	20	0	0	0	76
Monroe	1	20	2	1	0	0	24	5	25	4	0	0	0	34
Morgan	1	5	0	0	0	0	6	3	6	0	0	0	0	9
Muskingum	0	1	0	1	0	0	2	0	1	0	7	11	0	19
Noble	16	9	0	0	0	0	25	6	8	0	0	0	0	14
Perry	1	0	5	7	0	0	13	2	0	10	8	0	0	20
Pike	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Portage	0	0	0	0	2	0	2	0	0	0	0	0	0	0
Putnam	0	0	0	0	0	0	0	0	3	0	0	0	0	3
Richland	1	0	3	0	0	0	4	0	0	0	0	0	0	0
Sandusky	0	1	0	0	0	0	1	0	1	0	0	0	0	1
Scioto	0	0	0	0	0	0	0	6	0	0	0	0	0	6
Seneca	1	2	0	0	0	0	3	8	2	0	0	0	0	10
Shelby	0	1	0	0	0	0	1	0	3	0	0	0	0	3
Stark	2	0	0	0	3	0	5	1	0	1	2	36	0	40
Summit	0	0	0	2	2	0	4	0	0	0	5	2	0	7
Trumbull	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Tuscarawas	2	1	0	0	1	1	5	0	1	0	0	6	0	7
Van Wert	0	1	0	0	0	0	1	0	1	0	0	0	0	1
Vinton	2	0	1	0	0	0	3	0	4	0	0	0	0	4
Washington	21	23	0	0	0	0	44	28	38	1	0	0	0	67
Wayne	3	0	0	3	0	0	6	0	0	0	1	0	0	1
Wood	0	3	0	0	0	0	3	0	2	0	0	0	0	2
Wyandot	0	12	0	0	0	0	12	0	12	0	0	0	0	12
Total	137	144	41	37	9	1	369	192	248	99	57	56	1	653

Licking, Medina, Meigs and Columbiana counties. The most successful operations occurred in Meigs County, where 49 gas producers were obtained from a total of 57 tests drilled to the Berea sand.

Shallow Sands Field of Southeastern Ohio

This field includes a number of producing sands belonging to the Pennsylvanian and Mississippian series above the Berea sand. Some important producing sands in this field are the Weir, Squaw, Big Injun, Keener, Maxton, Macksburg 500-ft., First Cow Run, Mitchell and Goose Run. Depths in this field are generally less than 2000 ft. About 265 wells were drilled to the shallow sands in 12 counties of the field and production was secured in 9 counties. Of the total number, 113 tests, or 42.5 per cent, were dry holes whereas 57.5 per cent were producers. Drilling activity centered in Meigs, Athens, Monroe, and Washington counties, where 60 per cent of the 218 tests drilled during the year yielded oil and/or gas.

Production

According to the United States Bureau of Mines, Ohio produced 4,232,000 bbl. of oil in 1934, which was a daily average production of 11,600 bbl. Production for 1935 is estimated at 4,080,000 bbl.[1]

Ohio produced 50,330 million cu. ft. of natural gas in 1934[2], an increase of 2449 million cubic feet over 1933 production. A further increase is indicated for 1935 by estimates of 52,000 million cu. ft. for the year[1].

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[1] Estimates by R. J. Hopkins.
[2] U. S. Bureau of Mines.

Petroleum Development in Oklahoma in 1935

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(New York Meeting, February, 1936)

Activity in the oil and gas fields of Oklahoma was more pronounced in 1935 than in 1934, with 2320 completions, an increase of about 21 per cent. The state produced approximately 185,000,000 bbl. in 1935. Osage County and shallow pools in northeastern Oklahoma showed considerable activity.

The assembly of a complete table of the oil fields of the state (Table 1) was not achieved, as many of the early records of operators and pipe line companies are not complete, and data for the older fields will perhaps never be fully tabulated. Table 1 includes all of the new fields and most of the important fields of the State of Oklahoma.

Increased Field Activities

The discovery of large production in the deep Simpson group in the old Fox field in Carter County in the southern part of the state, the discovery of new producing horizons in the Fitts pool, and the extension of Wilcox production in the "Mansion" area at Oklahoma City were the outstanding developments in Oklahoma in 1935. Wildcatting resulted in the discovery of new pools such as Jesse, Hoyt, Grayson, South Keokuk, Wofford, Britton and Stillwater. The Fitts and Edmond pools were rapidly developed during the year.

Fox Pool.—Deep production in southern Oklahoma became a reality in October when the Williams No. 1 well of Carter Oil Co. and others, in the Fox pool, began producing oil at the rate of 10,000 bbl. per day from a depth of 8088 ft. After flowing wild several days, the well was killed after pipe stuck and a difficult fishing job resulted. The job had not been completed at the end of the year 1935. This test, considered one of the most important oil discoveries in the Mid-Continent area, opened the entire South Oklahoma area to a deep exploration campaign for Simpson production and production in the Pennsylvanian series on the south flank of the Arbuckle Mountains.

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Fitts Pool.—The Fitts pool enjoyed the distinction of holding first place in development during 1935. One hundred ninety-seven wells were completed in the Upper Simpson Horizon. The E. H. Moore-Atkins No. 3 well, in the NW.¼ of sec. 32, T. 2 N., R. 7 E., discovered the Wilcox horizon on Sept. 11, 1935. Many wells were deepened to the McLish sand from the Bromide sand. The pool has been defined on all sides except the east, where present development is active. In 1936 the Fitts pool probably will undergo rapid development towards the east and the Wilcox zone will be tested further. Eight producing sands have been productive of oil or gas.

Jesse Pool.—The Jesse pool in Pontotoc County was opened on Nov. 27, 1935, by the Continental Oil Co. with its McCarty No. 1 well in the NW.¼ of sec. 12, T. 1 N., R. 7 E. This well made an initial production of over 12,000 bbl. The well is about 5½ miles east of the Fitts pool and apparently is in the same type of structure.

Edmond Pool.—The Edmond pool in 1935 was featured by wells with large capacity producing from a thick Wilcox sand. Erratic geological conditions have made drilling hazardous. Thirty-two wells were completed during the year.

Other Pools.—Wilcox sand production in the Fish pool in Seminole County came to the forefront during the year. About 30 wells were completed. The Olympic pool, Hughes County showed rapid development toward the close of the year, after the discovery of Senora sand production. The Dill pool, Okfuskee County, showed slow but steady development.

Wildcats.—Several wildcats proved to be major disappointments. The failure of the Carter Oil Co. in the deep test on the Centrahoma dome in Western Coal County dashed hopes for the discovery of another Fitts pool. The Midco Petroleum Corporation-Yost No. 1-A in the old Billings pool in Noble County discovered oil in the Arbuckle lime, but water soon dispelled hopes for a producer. The Helmerich and Payne-Crouse No. 1 in Grant County looked favorable, but the hole was later junked. Other wildcats, in Cleveland, Oklahoma, McClain and Logan Counties, were failures.

Lucien.—Development in Lucien during the year was practically centered in the southeast extension with the field extending into Logan County. Misener sand production was discovered by the Stanolind-Frederick No. 2 well in the SE.¼ of sec. 28, T. 20 N., R. 2 W.

Polo Pool.—The Polo pool was developed slowly during the year. The Atlantic Oil Producing Company's Porter No. 1 well in the N.½ SW.¼ sec. 22, T. 22 N., R. 2 W. in May of this year was an important north extension. The pool was defined on the east side with the failure of the Stanolind-Shoop No. 1 in the SW.¼ of the SE.¼ of sec. 27, T. 22, R. 2 W. At the close of the year the Shell-Watts No. 1 in the SW.¼ of the

TABLE 1.—*Oil and Gas Production in Oklahoma during* 1935

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
1	Allen[1], *Pontotoc*	22	3,000	0	0	3,000	37,264,463	3,065,168	2,896,745	5,867
2	Altus, *Jackson*	2	*y*	*y*	*y*	*y*	*y*	*y*	117,710	475
3	Asher-Wanette, *Pottawatomie*	6	675	0	0	675	6,498,501	466,141	307,838	734
4	Bethel, *Seminole*	11	500			500	1,868,000	50,000	48,000	114
5	Billings, *Noble*	20	600	0	60	660	*y*	36,794	77,160	328
6	Binger, *Caddo*	2	10	0	0	10	10,811	0	10,811	29
7	Bowlegs, *Seminole*	9	3,820	0	0	3,820	100,129,289	3,953,664	3,808,387	8,989
8	Braman, N. and S., *Kay*	12	910	185		1,095	19,316,446	543,800	519,710	1,450
9	North Britton, *Oklahoma*	½	320	0	0	320	14,687	0	14,687	83
10	South Britton, *Oklahoma*	½	320	0	0	320	60,183	0	60,183	310
11	Brock, *Carter*	14	600	0	0	600	3,621,000	155,000	142,000	381
12	Burbank[2,3], *Osage, Kay*	15	22,170	0	0	22,170	187,889,000	3,341,000	3,057,000	7,899
13	Caldwell[4], *Grant*	7	30	0	0	30	182,000	8,600	3,560	30
14	Carr City, *Seminole*	8	1,060	0	0	1,060	22,814,000	1,998,000	2,003,000	5,218
15	Carter-Knox, *Grady, Stephens*	11	1,840	0	0	1,840	11,357,000	604,000	595,000	1,518
16	Cement, *Caddo*	19	2,325	0	0	2,325	12,535,000	699,544	615,455	1,648
17	Chandler[5], *Lincoln*	11	1,160	0	0	1,160	*y*	*y*	1,788,032	4,212
18	Cleveland[6], *Pawnee*	32	9,720	0	0	9,720	53,330,427	620,659	636,610	1,820
19	Crescent, *Logan*	3	1,280	1,320	40	1,320	3,436,568	1,276,459	1,944,972	5,273
20	Cromwell, *Seminole*	11	4,780	0	0	4,780	50,217,000	1,696,000	1,546,000	3,909
21	Cushing, *Creek*	24	23,528	0	0	23,528	324,202,050	4,538,140	4,722,283	12,002
22	Davenport, *Lincoln*	10	0	2,000	0	2,000	11,695,213	273,397	227,244	550
23	Deep Rock, *Payne*	11	520	0	80	600	*x*	*x*	*x*	*x*
24	Dill, *Okfuskee*	2	640	0	0	640	215,090	28,064	187,526	714
25	Dilworth, *Kay*	21	5,280	0	2,720	8,000	*y*	217,059	*y*	*y*
26	Earlsboro, *Pott.-Seminole*	10	4,730	0	0	4,730	116,531,839	2,993,500	3,078,209	7,469
27	East Earlsboro, *Seminole*	7	2,000	0	0	2,000	32,650,895	2,410,444	2,156,403	5,239
28	South Earlsboro, *Seminole*	6	300	0	0	300	7,681,000	401,000	433,000	1,040
29	Edmond, *Oklahoma*	6	620	80	0	700	1,595,201	95,212	1,478,309	7,210
30	Fairfax[7], *Osage*	10	*y*	*y*	*y*	*y*	*y*	2,556,716	*y*	*y*
31	Fitts-Upper Simpson, *Pontotoc*	2	*y*	*y*	*y*	*y*	6,877,304	162,942	6,714,362	32,502
32	Fitts-Hunton, *Pontotoc*	2	*y*	*y*	*y*	*y*	56,731	8,359	48,372	530
33	Fitts-Wilcox, *Pontotoc*	1	*y*	*y*	*y*	*y*	26,667	0	26,667	0
34	Fox, *Carter*	20	1,110	0	420	1,530	11,600,000	250,000	275,000	625
35	Fox, *Carter*	1	?	?	*x*	?	8,964	0	8,964	0
36	Garber, *Garfield*	20	3,840	0	0	3,840	47,745,387	875,869	761,828	2,022
37	Gessman, *Lincoln*	2	0	110	0	110	205,089	26,162	178,927	227
38	Glenn, *Creek*	31	14,720*y*	0	0	14,720*y*	*x*	*x*	*x*	*x*
39	Graham, *Carter*	18	2,520	0	220	2,740	23,950,000	700,000	650,000	1,700
40	Gray, *Pottawatomie*	4	180	0	0	180	2,164,000	806,000	624,000	1,644
41	Grayson, *Seminole*	1	*y*	*y*	*y*	*y*	245,552	0	245,552	1,075
42	Grisso, *Pottawatomie*	2	80	0	0	80	113,000	21,800	92,200	266
43	Healdton, *Carter*	22	8,100	0	0	8,100	170,613,000	3,382,000	3,391,000	8,991
44	Hewitt, *Carter*	17	3,450	0	0	3,450	80,188,000	1,814,000	1,702,000	4,462
45	Hominy, *Osage*	16	300	0	0	300	1,851,076	35,256	42,804	103
46	East Hominy, *Osage*	15	450	0	0	450	1,883,389	36,199	47,731	96
47	Hoyt, *Lincoln*	1	*y*	*y*	*y*	*y*	58,257	0	58,257	112
48	Hubbard, *Kay*	12	620	0	0	620	5,591,048	242,079	280,378	791
49	Hull, *Logan*	2	*y*	*y*	*y*	*y*	62,985	21,086	41,899	*y*
50	Jesse, *Pontotoc*	1	10	0	10	10	18,088	0	18,088	465
51	Josey, *Okfuskee*	13	0	300	10	310	4,719,506	154,064	126,945	333

[a] Footnotes to column heads and explanation of symbols are given on page 215.
[1] Includes West Allen.
[2] South Burbank, included with Fairfax, below.
[3] Part of field under repressuring.
[4] Major portion of field in Kansas.
[5] Includes West Chandler.
[6] Includes Landerdale and North Terlton.
[7] Includes South Burbank.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1935		At End of 1935				
	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	12,421	*y*	26	*x*	*x*	*x*	*x*	314	*y*	*y*	*y*	226	0	0	226
2	*y*	*y*		*x*	*x*	*x*	*x*		*y*	*y*	*y*	*y*	*y*	*y*	*y*
3	9,627	*y*	*y*	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
4	3,736		3	*x*	*x*	*x*	*x*	52	0	0	*x*	*x*	*x*	*x*	37
5	*y*	*y*	*y*	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
6	108	*x*	29	0	0	0	0	1	0	0	0	1	0	0	1
7	26,212	*y*	37	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	243	0	0	243
8	17,640	1,176	24	*x*	*x*	*x*	*x*	144	0	10	12	60	0	0	60
9	46	0	42	*x*	*x*	*x*	*x*	3	3	0	1	2	0	0	2
10	188	0	77	*x*	*x*	*x*	*x*	5	5	0	0	5	0	0	5
11	6,070	*y*	3.1	*x*	*x*	*x*	*x*	139	0	0	0	121	0	0	121
12	8,475	*y*	4.0	*x*	*x*	*x*	*x*	2,200	0	28	0	1,950	0	0	1,950
13	6,100	1 and 20	30	*x*	*x*	*x*	*x*	2	1	0	0	0	2	0	2
14	21,600	*x*	55	*x*	*x*	*x*	*x*	113	0	2	0	94	0	0	94
15	6,172	*x*	9.3	*x*	*x*	*x*	*x*	220	6	12	*x*	163	*x*	*x*	163
16	5,391	*y*	*y*	*x*	*x*	*x*	*x*	250*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
17	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
18	5,487	*x*	3	*x*	*x*	*x*	*x*	1,147	1	*x*	*x*	566	0	0	566
19	2,685	92.6	165	8,386*y*	2,251*y*	2,808*y*	100*y*	33	9	0	1	0	32	1	33
20	10,506	*x*	14.4	*x*	*x*	*x*	*x*	491	1	9	0	272	0	0	272
21	13,779	*x*	6	*x*	*x*	*x*	*x*	3,528	18	*x*	*x*	1,969	0	0	1,969
22	5,848	117	3.72	*x*	*y*	*y*	*y*	210	0	*y*	*y*	0	148	0	148
23	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
24	336	*y*	*y*	*x*	*x*	*x*	*x*	11	11	1	0	*y*	*y*	*y*	11
25	*y*	*y*	*y*	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
26	24,637	*y*	*y*	*y*	*x*	*x*	*x*	495	*y*	*y*	*y*	*y*	*y*	*y*	*y*
27	16,325	*y*	*y*	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
28	25,600	1,020	45	*x*	*x*	*x*	*x*	30	0	*x*	*x*	23	0	0	23
29	2,279	*y*	228	651,626	40,280	611,346	*y*	37	32	0	0	36	1	0	37
30	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
31		*y*	*y*	*y*	*x*	*y*	*y*	219	197	0	0	0	197	*y*	*y*
32	*y*	*y*	*y*	*y*	*y*	*y*	*x*	7	4	0	0	*y*	*y*	*y*	7
33	*y*	*y*	*y*	*y*	0	*y*	*y*	2	2	0	0	0	2	0	2
34	10,500	*y*	6	78,000[9]	4,000[9]	3,000[9]	*y*	142	0	1	*x*	97	0	38	135
35	*x*	*x*	0	0	0	0	0	0	0	0	0	0	0	0	0
36	12,434	*y*	3	*x*	*x*	*x*	*x*	872	1	*x*	*x*	584	0	0	584
37	1,625	136	23	*x*	*x*	*x*	*x*	10	8	0	0	0	10	0	10
38	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
39	9,500	410	6	47,200	1,400	1,200	*x*	322	0	0	*x*	0	300	18	318
40	12,000	480	117	*x*	*x*	*x*	*x*	14	*x*	*x*	*x*	*x*	*x*	*x*	14
41	*y*	*y*	90	*x*	0	*x*	*x*	12	12	0	0	12	0	0	12
42	1,420	*x*	8.9	*x*	*x*	*x*	*x*	3	2	0	0	3	0	0	3
43	21,063	*x*	4.8	*x*	*x*	*x*	*x*	2,162	20	39	*x*	1,872	0	0	1,872
44	23,243	*x*	5.5	*x*	*x*	*x*	*x*	898	2	*x*	*x*	810	0	0	810
45	6,173	110	9.3	0	0	0	0	37	0	1	0	11	0	0	11
46	4,140	83	3	0	0	0	0	66	1	6	0	25	0	0	25
47	*y*	*y*	28	*x*	*x*	*x*	*x*	6	6	0	0	*y*	*y*	*y*	6
48	9,018	*y*	*y*	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
49	*y*	*y*	*y*	*x*	*x*	*x*	*x*	2	0	0	0	2	0	0	2
50	1,809	*y*	465	*y*	0	*y*	*y*	1	1	0	0	0	1	0	1
51	15,730	*x*	11	*x*	*x*	125	*y*	32	0	0	0	0	29	1	30

[9] Estimated.

TABLE 1.—(*Continued*)

	Average Depth, Ft.		Oil Production Methods at End of 1935						Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935				
			Number of Wells							Average at End of		Gravity A.P.I. at 60° F.				
Line Number	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Misc.	Injection into Reservoir[d]	Initial	1934	1935	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	2,600	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
2	1,500	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*x*	*y*	*y*	44	*y*	*y*	*y*	*y*
3	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*
4	3,300	3,280	0	37	0	0	0	0	*x*	*x*	*x*	40	32	37	*x*	*x*
5	2,100	2,000	*y*	*y*	*y*	*y*	*y*	*y*	*x*	*x*	*x*	42	41	*x*	*x*	P
6	11,230	11,195	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
7	4,300	4,100	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*x*	*x*	40	0.3	*x*
8	3,402	1,934	0	60	0	0	0	4G	*x*	*x*	*x*	43	36	41	0.3	M
9	6,706	6,547	2	0	0	0	0	0	2,000	0	2,000	50	40	44	*x*	P
10	6,749	6,609	5	0	0	0	0	0	2,200	0	2,200	44	37	39	*x*	P
11	2,100	Var.	0	121	0	0	0	0	*x*	*x*	*x*	38	25	35	0.8	A
12	2,700–3,000	*x*	0	1,950	0	0	0	0	*x*	*x*	*x*	*x*	*x*	38	*x*	P
13	4,785	4,779	0	2	0	0	0	0	*x*	*x*	*x*	*x*	*x*	40	0	M
14	4,205	4,180	*x*	*x*	*x*	*x*	*x*	*x*	*e*320	*e*100	*x*	*x*	*x*	40	0.3	M
15	1,720–2,100	*x*	0	163	0	0	0	*x*	*x*	*x*	*x*	38	26	35	*x*	*x*
16	2,800	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*y*	*y*	*y*	37	34.7	*x*	*y*	*y*
17	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
18	2,400	1,700	0	*y*	0	0	0	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
19	6,219	6,190	32	0	0	0	0	0	*e*2,920	*e*,2157	*e*1,741	43.3	41.8	*y*	0.2	M
20	3,400	*x*	0	272	0	0	0	0	*x*	*x*	*x*	*x*	*x*	35	*x*	*x*
21	2,800	2,200	0	1,969	0	0	0	0	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
22	3,440	3,390	0	148	0	0	0	G3	*y*	*y*	*y*	48	36	45	*y*	M
23	4,250	4,200	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	40	*y*	M
24	3,930	3,900	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	43.9	39	41	*y*	P
25	Various	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	42.7	38	40	*y*	P
26	4,300	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
27	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
28	4,225	4,200	0	23	0	0	0	0	*e*550	*e*370	*y*	*x*	*x*	40	0.3	M
29	*y*	*y*	36	0	1	0	0	0	*e*2,900	*e*2,829	*e*2,640	52	38	39	*y*	P
30	2,800	2,750	*y*	*y*	*y*	*y*	*y*	*y*	900	*y*	800	42	38	*y*	*y*	*y*
31	4,325	*x*	216	2	1	0	0	0	*x*	*e*1,811	*e*1,419	*y*	*y*	*y*	*y*	P
32	3,700	3,350	7	0	0	0	0	0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	P
33	4,415	*y*	2	0	0	0	0	0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	P
34	2,500	2,200	0	135	0	0	0	0	500 to 1,200	*x*	*x*	35	27	31	*x*	M
35	8,088	6,694	0	0	0	0	0	0	*x*	0	0	*y*	*y*	*y*	*y*	*y*
36	4,200	1,100	0	584	0	0	0	0	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
37	3,065	3,050	0	10	0	0	0	0	*e*1,285	*y*	250	48	45	47	*y*	M
38	1,575	1,475	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	35	*y*	P
39	2,800	2,400	0	300	0	0	0	0	750	*x*	*x*	36	26	32	*y*	M
40	3,500	3,475	0	14	0	0	0	0	*e*1,440	*x*	*x*	*x*	*x*	40	*x*	M
41	3,850	3,750	0	12	0	0	0	0	*x*	*y*	*y*	*y*	*y*	33	*y*	*y*
42	4,050	4,130	0	3	0	0	0	0	*x*	*x*	*x*	*x*	*x*	35	*x*	M
43	750–1,900	*y*	0	1,872	0	0	0	0	*x*	*x*	*x*	32	29	31	*x*	*x*
44	1,500–2,000	*y*	0	810	0	0	0	0	*x*	*x*	*x*	36	31	34	*x*	*x*
45	2,685	2,625	0	11	0	0	0	0	*x*	*x*	*x*	36	35	35.5	0	P
46	2,210	2,160	0	25	0	0	0	0	*x*	*x*	*x*	37.9	36.9	37.4	0	P
47	5,100	*y*	*y*	*y*	*y*	*y*	*y*	0	*y*	*y*	*y*	*y*	*y*	42	*y*	P
48	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	53.1	37.5	*y*	*y*	*y*
49	4,800	*y*	*y*	*y*	*y*	*y*	*y*	0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
50	4,633	4,621	1	0	0	0	0	0			*e*1,938			41	*y*	P
51	3,650	3,600	0	29	0	0	0	0	*x*	*y*	*y*	44	41	43	*y*	P

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Depth of Hole, Ft.
1	*y*	*y*	Cromwell, Wilcox	Pen, Ord	S	Por	*y*	AF	66	*y*	*y*
2	*y*	*y*	Granite Wash	Pen	S	Por	*y*	D	*y*	*y*	*y*
3	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
4	*x*	*x*	Booch	Per	S	Por	*y*	AF	8	Wilcox	4,385
5	*x*	*x*	Hoover	Pen	S	Por	50	A	11	Arbuckle	5,031
6	*y*	*y*	Binger	Pen	S	Por	35				
7	*x*	*x*	Wilcox or Simpson	Ord	S	Por	*x*	A	*y*	Wilcox or Simpson	4,913
8	1,440	4.7	Various	Pen-Ord	SL	Por	*y*	A	15	Arbuckle	3,553
9	*x*	*x*	Simpson	Ord	D, L	Por	51	AF	1	2d Wilcox	6,785
10	*x*	*x*	Simpson	Ord	D, L	Por	52	A	1	2d Wilcox	6,931
11	*x*	1.25	Various	Pen	S	Por	*x*	AF	46	Ord, Lime	3,000
12	*x*	*x*	Burbank	Pen	S	Por	*x*	ML	75	Granite	4,240
13	*x*	*x*	Wilcox	Ord	S	Por	6	A	1	Wilcox	4,785
14	*x*	2	Hunton, Wilcox	Sil, Ord	LS	Por	*x*	A	13	Wilcox	4,210
15	*x*	*x*	Various	Per	S	15–20	15	AF	63	Lower Deese	8,963
16	*x*	*x*	Caddo, Fortuna	Per-Pen	S	*y*	*y*	*y*	*y*	Pennsylvanian	10,079
17	*y*	*y*	Wilcox	Ord	S	Por	*x*	A	*y*	*y*	*y*
18	*x*	*x*	Cleveland-Bartlesville	Pen	S	Por			*y*	Arbuckle L	*y*
19	1,500	2	Layton-2d Wilcox	Pen-Ord	S	23	Layton —26 Wilcox —29	AF	2	2d Wilcox	6,372
20	*x*	*x*	Cromwell	Pen	S	Por	*x*	AF	55	Wilcox	4,226
21	*x*	*x*	Numerous Horizons	Pen-Ord	S, L	Por	*x*	AF	*x*	Granite	3,750
22	*y*	3	Prue	Pen	S	Por	50	ML	18	Wilcox	4,666
23	*y*	*y*	Wilcox, Bartlesville	Pen-Ord	S	Por	50	A	3	Arbuckle	4,542
24	*y*	*y*	Hunton, Cromwell	Sil, Pen	S, L	Por	30	*y*	*y*	Wilcox	4,225
25	*y*	*y*	Various	Per, Pen, Ord	S, SL	Por	*y*	A	*y*	Arbuckle	4,243
26	*y*	*y*	Earlsboro-Wilcox	Pen-Ord	*y*	*y*	*y*	*y*	97	*y*	*y*
27	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
28	*x*	3	Wilcox	Ord	S	Por	25	A	4	Wilcox	4,225
29	*x*	*x*	Wilcox	Ord	S	Por	*y*	A	2	Simpson	6,853
30	*y*	*y*	Burbank	Pen	S	20–25	*y*	ML	*y*	*y*	*y*
31	*x*	*x*	Bromide, McLish	Ord	S	Por	*y*	*y*	3	*y*	*y*
32	*x*	*x*	Hunton	Sil	L	Por	250	*y*	*y*		
33	*x*	*x*	Wilcox	Ord	S	Por	*y*	*y*	*y*	*y*	*y*
34	*y*	*y*	Deese	Pen	S	30	100	A	25	Dornick Hills	4,200
35	0	0	?	Ord	S	*x*	*x*	AF	*x*		
36	*x*	*x*	Various	Per-Pen-Ord	S, L	Por	*y*	AF	*y*	Granite	*x*
37	*y*	2	Cleveland	Pen	S	Por	12	N	4	Wilcox	5,002
38	*y*	*y*	Glenn, Wilcox	Pen-Ord	S	Por		ML		Arbuckle	2,964
39	*y*	1.0	Deese	Lower Pen	S	28–30	Oil 45 Gas 70	A	40	Dornick Hills	5,108
40	*x*	*x*	Wilcox	Ord	SL	Por	25	A	1	Wilcox	3,500
41	*x*	*x*	Hunton, Simpson, Dolomite	Sil, Ord	SL		80	*y*	*y*	*y*	*y*
42	*x*	*x*	Hunton	Sil	L	*x*	*x*	A	*x*	Wilcox	4,860
43	*x*	*x*	Various	Pen-Ord	SL	Por	*x*	AF	167	Arbuckle	*x*
44	*x*	*x*	Hoxbax	Pen	S	15–20	50	AF	76	Arbuckle	*x*
45	*x*	*x*	Burgen-Siliceous Lime	Ord	S, Dol	*x*	60-S 50-L	A	8	Arbuckle	3,206
46	*x*	*x*	Bartlesville	Pen	S	*x*	50	A	16	Arbuckle	2,857
47	*x*	*x*	1st Wilcox	Ord	S	Por	15		*y*	*y*	*y*
48	*y*	*y*	Various	Pen-Ord	SL	Por	*y*	AF	*y*	Arbuckle	3,761
49	*y*	*y*	Layton	Pen	S	Por	*y*	*y*	*y*	*y*	*y*
50	*y*	*y*	McLish	Ord	S	Por		AF	*y*		
51	*y*	2.2	Wilcox	Ord	S	*x*	50	D	15	Wilcox	3,700

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
52	Keokuk Falls, *Seminole*	3	*y*	*y*	*y*	*y*	1,155,615	375,064	592,714	1,729
53	Keokuk Falls, *Seminole*	1	*y*	*y*	*y*	*y*	6,573	0	6,573	141
54	South Keokuk, *Seminole*	1	300	0	0	300	152,919	0	152,919	920
55	Laffoon, *Lincoln*	3	60	0	0	60	375,000	78,000	281,000	745
56	Langston, *Logan*	2	160	0	0	160	172,000	73,000	99,000	198
57	Lincreek, *Lincoln-Creek*	20	160	0	0	160	615,379	194,349	126,519	338
58	Little River, *Seminole*	9	4,900	0	0	4,900	101,998,974	4,832,569	5,088,639	14,233
59	East Little River, *Seminole*	8	640	0	0	640	15,256,877	263,950	302,097	835
60	Lucien, *Noble*	3	0	4,160	0	4,160	6,882,100	2,871,863	3,915,000	10,675
61	Lucien, *Noble*	1	10	0	0	10	36,744	0	36,744	101
62	Lucien, *Noble*	1	10	0	0	10	51,788	15,225	36,563	101
63	Marathon, *Noble*	1	*y*	*y*	*y*	*y*	42,175	0	42,175	126
64	Marshall, *Logan*	9	700	240	0	940	13,339,231	1,886,663	273,746	848
65	Maud, *Pott-Seminole*	7	1,440	0	0	1,440	10,508,000	443,000	416,000	968
66	Meeker, *Lincoln*	1	10	0	0	10	8,052	8,052	0	0
67	Mission, *Seminole*	9	*y*	*y*	*y*	*y*	21,708,805	1,258,832	1,126,337	2,824
68	Moore, *Cleveland*	1	0	10	0	10	249,082	0	249,082	175
69	Naval Reserve, *Osage*	8	2,720	2,880	160	2,880	6,844,114	2,916,374	3,066,914	8,930
70	Newman, *Hughes*	12	*y*	*y*	*y*	*y*	96,128	*x*	4,986	14
71	Nicoma Park, *Oklahoma*	6	*y*	*y*	*y*	*y*	275,869	25,087	25,585	68
	Oklahoma City, *Oklahoma*									
72	Wilcox	6	3,670	20	0	3,690	198,590,094	47,210,407	43,997,824	109,580
73	Lower Simpson	7	5,566	884	0	6,450	81,559,567	13,237,036	8,196,061	21,137
74	Arbuckle	7	570	1,020	0	1,590	17,421,152	95,054	48,711	124
75	Cleveland	7	80	0	0	80	827,464	219,876	607,588	2,384
76	Highley	3	10	0	0	10	153,236	101,212	52,024	82
77	Total		9,896	1,904	0	11,820	298,551,513	60,863,585	52,902,208	133,226
78	Olympic, *Hughes*	2	*y*	*y*	*y*	*y*	129,166	11,268	117,898	1,319
79	Otoe City, *Noble*	5	10	0	0	10	54,082	4,866	4,870	13
80	Otstott, *Kay*	18	3,300	0	0	3,300	3,472,984	227,361	228,441	632
81	Papoose, *Hughes, Okfuskee*	12	2,400	0	0	2,400	22,795,000	481,000	446,000	1,220
82	Pettit, *Osage*	16	380	0	0	380	3,664,166	48,288	40,591	*y*
83	Polo, *Noble*	2	390	0	0	390	1,263,148	103,148	1,160,000	3,386
84	Ponca City, *Kay*	25	1,670	0	0	1,670	5,869,678	118,874	112,978	334
85	North Ripley, *Payne*	8	0	90	0	90	*y*	*y*	*y*	*y*
86	Robberson, *Garvin*	15	0	1,480	320	1,800	11,870,000	465,000	400,000	1,060
87	Roff, *Pontotoc*	18	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
88	St. Louis, *Pott.-Seminole*	10	7,300	0	0	7,300	95,457,452	7,440,169	8,138,521	19,861
89	Sasakwa, *Seminole*	8	560	0	0	560	7,009,673	353,900	292,015	915
90	East Sasakwa, *Hughes*	1	10	0	0	10	18,657	0	18,657	302
91	East Sasakwa, *Hughes*	1	*y*	*y*	*y*	*y*	54,148	0	54,148	441
92	Sasakwa Townsite, *Seminole*	3	120	0	0	120	1,244,604	483,806	536,798	1,163
93	Searight, *Seminole*	10	1,300	0	0	1,300	30,732,143	838,252	1,047,013	2,537
94	North Searight, *Seminole*	2	310	0	0	310	383,152	46,994	336,158	1,469
95	Seminole City, *Seminole*	10	3,640	0	0	3,640	111,501,987	3,683,282	3,993,488	11,851
96	East Seminole, *Seminole*	10	510	0	0	510	4,450,000	390,912	441,008	1,359
97	West Seminole, *Seminole*	6	260	0	0	260	7,592,000	1,216,000	1,260,000	4,836
98	Seward, *Logan*	1	10	0	0	10	*y*	*y*	*y*	0
99	Shawnee, *Pottawatomie*	2	*y*	*y*	*y*	*y*	148,239	28,103	120,136	400
100	Sholom Alechem, *Carter and Stephens*	12	4,180	0	220	4,400	30,217,000	1,586,000	1,417,000	3,850
101	Stillwater, *Payne*	1	120	0	0	120	39,000	0	39,000	200
102	Tatums, *Carter*	9	2,200	0	0	2,200	13,300,000	2,407,000	1,743,000	4,350
103	Thomas, *Kay*	12	140	0	0	140	5,381,119	60,995	101,119	309
104	Tipton, *Jackson*	1	*y*	*y*	*y*	*y*	20,117	0	20,117	230
105	Tonkawa, *Kay and Noble*	15	2,300	500	0	2,800	117,461,104	1,386,929	1,203,517	3,303
106	Vernon, *Kay*	12	920	0	0	920	2,633,882	178,266	280,378	*y*
107	Vines, *Murray*	16	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
108	Watchorn, *Pawnee*	20	0	320	0	320	*x*	131,170	116,792	Layton 148 Wilcox 110
109	Wewoka and Wewoka Townsite, *Seminole*	13	2,150	0	0	2,150	38,870,318	1,629,124	1,323,796	*y*
110	Wheeler, *Carter*	20		540	160	700	1,138,000	37,000	38,000	110
111	Wilzetta, *Lincoln*	2	200	0	0	200	253,000	141,000	112,000	331

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Producing Oil and Gas[c]	At End of 1935: Producing Gas Only	At End of 1935: Total Producing
52	y	y	64	y	y	y	y	26	14	0	0	26	0	0	26
53	y	y	141	x	x	x	x	1	1	0	0	1	0	0	1
54	5,097	y		x	x	x	x	13	13	0	0	13	0	0	13
55	6,250	x	373	x	x	x	x	2	0	0	0	2	0	0	2
56	1,075	x	66	x	x	x	x	y	y	y	y	y	3	0	3
57	3,846	y	y	y	y	y	y	y	y	y	y	y	y	y	y
58	20,816	y	y	x	x	x	x	y	y	y	y	y	y	y	y
59	23,839	y	y	x	x	x	x	y	0	y	y	y	y	y	y
60	1,895	x	133	8,000y	3,000y	4,000y	x	79	24	0	0	0	80	0	80
61	3,674	y	101	x	x	x	x	1	1	0	0	1	0	0	1
62	5,179	y	101	x	x	x	x	1	0	0	0	1	0	0	1
63	x	x	126	x	x	x	x	1	1	0	0	1	0	0	1
64	14,190	x	45	14,500y	x	2,500y	x	53	0	12	2	19	0	9	28
65	7,300	220	10	x	x	x	x	140	x	x	x	x	x	x	100
66	852	x	0	x	x	0	0	1	0	1	0	0	0	0	0
67	y	y	y	x	x	x	x	y	y	y	y	y	y	y	y
68	24,908	x	175	y	0	y	y	1	1	0	0	0	1	0	1
69	2,512	36	56	3,006	952	2,054	7.5	174	60	2	0	160	0	8	168
70	x	x	14	x	x	x	x	1	0	0	0	1	0	0	1
71	x	x	34	0	0	0	0	2	1	0	0	2	0	0	2
72	53,818	448	220	y	y	y	y	606	44	12	50	506	0	2	508
73	12,645	90	76	x	x	x	x	467	7	50	57	278	0	68	346
74	10,957	y	13	x	x	x	y	106	0	2	33	10	0	59	69
75	10,343	y	111	y	x	x	x	27	23	0	4	23	0	0	23
76	15,324	y	82	x	x	x	x	1	0	0	0	1	0	0	1
77	25,258	y	163	x	x	x	x	1,207	74	64	144	818	0	129	947
78	y	y	y	x	x	x	x	y	y	y	y	y	y	y	y
79	5,408	x	13	0	0	0	0	1	0	0	0	1	0	0	1
80	1,052	y	y	x	x	x	x	y	y	y	y	y	y	y	y
81	9,500	950	12	x	x	x	x	267	0	1	0	95	0	0	95
82	9,643	y	y	x	x	x	x	y	y	y	y	y	y	y	y
83	3,495	x	105	x	x	x	x	36	27	1	0	36	0	0	36
84	3,844	x	y	x	x	x	x	y	y	y	y	y	y	y	y
85	y	y	y	x	x	x	x	y	y	y	y	y	y	y	y
86	8,000	x	5	y	y	y	y	273	0	0	x	200	0	15	215
87	y	y	y	x	x	x	x	y	y	y	y	y	y	y	y
88	13,076	y	38	x	x	x	x	y	y	y	y	y	y	y	y
89	12,517	y	57	x	x	x	x	y	y	y	y	y	y	y	y
90	1,866	y	302	x	x	x	x	1	1	0	0	1	0	0	1
91	y	y	88	x	x	x	x	5	5	0	0	5	0	0	5
92	10,372	y	145	x	x	x	x	8	2	0	0	y	y	0	8
93	23,640	y	y	x	x	x	x	y	y	y	y	y	y	y	y
94	1,236	y	92	x	x	x	x	16	13	0	0	16	0	0	16
95	30,632	y	y	x	x	x	x	y	y	y	y	y	y	y	y
96	8,725	y	y	x	x	x	x	y	y	y	y	y	y	y	y
97	29,200	973	210	x	x	x	x	23	8	0	0	23	0	0	23
98	y	y	y	x	x	x	x	1	1	0	0	y	y	y	y
99	y	y	100	x	x	x	x	4	2	0	0	4	0	0	4
100	7,230	x	12	15,100y	y	y	x	362	0	7	0	0	323	15	338
101	320	50	100	x	0	x	x	4	0	4	0	0	4	0	4
102	6,050	103	22	0	0	0	0	202	7	1	0	201	0	0	201
103	3,844	y	y	x	x	x	x	y	y	y	y	y	y	y	y
104	y	y	115	x	x	x	x	2	2	0	0	2	0	0	2
105	41,950	x	7.2	x	x	x	x	898	0	y	21	458	0	10	458
106	2,863	y	y	x	x	x	x	y	y	y	y	y	y	y	y
107	y	y	y	x	x	x	x	y	y	y	y	y	y	y	y
108	y	y	24	x	x	x	x	40	0	0	1	Wilcox 10 Layton 5	0	0	15
109	18,079	y	y	x	x	x	x	y	y	y	y	y	y	y	y
110	2,100	y	2	500	0	0	0	100	0	0	x	70	0	0	70
111	1,265	x	83	x	x	x	x	4	0	0	0	4	0	0	4

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Flowing	Pumping	Gas-lift	Air-lift	Misc.	Injection into Reservoir[d]	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1934	Average at End of 1935	Character of Oil, Approx. Average during 1935, Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
52	4,113	4,085	y	y	y	y	y	0	e1,828	e1,710	e1,600	42	41.5	41.8	y	P
53	4,152	4,117	0	1	0	0	0	0	x	0	y	y	y	y	y	y
54	4,200	4,185	y	y	y	y	y	y	e1,728	0	e1,600	42	y	y	y	y
55	4,275	4,190	0	2	0	0	0	0	e1,872	x	x	x	x	22.5	x	A
56	5,145	5,100	0	3	0	0	0	0	x	x	x	x	x	40	x	M
57	3,700	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
58	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
59	y	y	y	y	y	y	y	y	y	y	y	41	37	x	x	P
60	5,200	5,000	60	10	10	0	0	0	2,200	1,729	1,542	44	38	43	0.2	P
61	4,982	4,972	y	y	y	y	y	0	y		y			42	y	P
62	4,983	4,970	y	y	y	y	y	0	y		y	y	y	y	y	y
63	4,480	4,446	0	1	0	0	0	0	1,665	x	x	y	y	y	x	y
64	6,039	3,900	0	0	19	0	0	0	1,950	x	x	41	36	40	0.3	M
65	4,140	4,130	0	140	0	0	0	0	e1,000y	50y	50y	x	x	39	0.35	M
66	5,461	5,455	0	0	0	0	0	0	x	x	0	x	x	32	x	x
67	y	y	y	y	y	y	y	y	y	y	y	x	x	y	y	y
68	7,291	7,245	1	0	0	0	0	0	2,750	0	y	y	y	y	y	y
69	2,650	2,590	40	134	0	0	0	0	x	x	x	41	36	38.5	0	P
70	3,710	3,693	0	1	0	0	0	0	x	x	x	x	x	x	x	x
71	6,200	6,140	2	0	0	0	0	0	x	x	x	x	x	39	x	P
72	6,500	6,350	55	297	151	1	2	0	e2,600y	x	x	x	x	38	0.2	P
73	6,500	6,200	17	145	115	0	1	0	e2,600y	y	y	y	y	36	0.2	P
74	6,500	6,100	6	0	4	0	0	0	e2,600y	y	y	42	31	37	0.2	P
75	5,850	y	5	8	10	0	0	0	y	y	y	37.7	36.6	37	y	P
76	6,659	6,650	1	0	0	0	0	0	x	y	y	y	y	y	y	P
77			73	450	280	1	3	0								
78	1,750	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
79	3,310	3,280	0	1	0	0	0	0	x	x	x	x	x	38	x	x
80	3,475	2,400	x	a	x	x	x	x	x	x	x	x	x	y	x	x
81	3,320	3,310	0	95	0	0	0	0	x	x	x	x	x	37	0.1	M
82	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
83	4,900	4,823	23	13	0	0	0	0	e2,014	e2,000	e1,560	44	40	y	x	P
84	y	y	y	y	y	y	y	y	y	y	y	44.5	38.4	y	y	y
85	4,259	4,199	y	y	y	y	y	y	y	y	y	40	y	y	y	M
86	1,400	1,300	0	200	0	0	0	0	600	x	x	33	25	28	y	M
87	500	y	y	y	y	y	y	y	y	y	y	22	19	y	y	A
88	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
89	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
90	4,136	y	y	y	y	y	y	0	y	y	y	y	y	y	y	y
91	2,762	y	y	y	y	y	y	0	y	0	y	y	y	y	y	y
92	y	y	y	y	y	y	y	0	y	y	y	y	y	y	y	y
93	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
94	4,600	y	0	16	0	0	0	0	y	y	e1,100	y	y	y	y	y
95	4,150	4,100	y	y	y	y	y	y	y	y	y	y	y	40	0.3	x
96	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
97	4,115	4,085	0	23	0	0	0	0	e500	e100	e75	x	x	40	x	M
98	6,332	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
99	4,457	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
100	3,300	2,900	0	323	0	0	0	0	760	x	x	35	27	32	y	M
101	4,300	4,306	4	0	0	0	0	0	e1,700	0	e1,500	40	40	40	y	M
102	2,400	2,250	0	201	0	0	0	0	500	x	x	31	21	28	y	M
103	y	y	y	y	y	y	y	y	y	y	y	56.7	40.2	y	y	y
104	2,635	2,595	0	2	0	0	0	y	y	y	y	y	y	41	y	y
105	4,216	1,819	0	458	0	0	0	40	x	x	x	44	41	42	0.2	M
106	y	y	y	y	y	y	y	y	y	y	y	42.3	36	y	y	y
107	y	y	y	y	y	y	y	y	y	y	y	16	15	y	y	A
108	Wil ox 4,100 Layton 2,750	x	0	15	0	0	0	0	840	x	x	x	x	Wilcox 42 Layton 40	x	P
109	4,100	3,200	y	y	y	y	y	y	y	y	y	y	y	y	y	y
110	1,050	1,000	0	70	0	0	0	0	300	x	x	21	17	20	y	M
111	4,290	4,240	0	4	0	0	0	0	e1,977	e1,970y	x	40	39	39.7	0	M

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Character of Gas: Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Porosity[i]	Producing Rock: Net Thickness, Average Ft.	Producing Rock: Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Deepest Zone Tested: Depth of Hole, Ft.
52	y	y	Misener Hunton	Mis, Sil	SL	10	20	A	y	Wilcox	4,483
53	y	y	Hunton	Sil	L	y	y	y	y	y	y
54	y	y	Misener Hunton	Mis-Sil	SL		15	y	y	y	y
55	x	x	Wilcox	Ord	S	Por	x	A	0	Wilcox	4,267
56	x	x	Wilcox	Ord	S	Por	x	A	0	Wilcox	5,246
57	y	y	Wilcox	Ord	S	Por	y	y	y	y	y
58	y	y	y	y	y	y	y	y	y	y	y
59	x	x	Cromwell-Wilcox	Pen, Ord	S	Por	x	A		Wilcox	4,754
60	1,500	1.0	Wilcox	Ord	L-S	Por	x	A	8	L. Simpson	5,411
61	y	y	Misener	Mis	S	Por	10	y	y		
62	y	y	Viola	Ord	L	Por	13	y	y		
63	x	x	Wilcox	Ord	S	Por	34	A	1	Wilcox	4,518
64	1,195	0.6	Various	Pen, Ord	S	Por	x	AF	16	Arbuckle	6,608
65	x	x	Misener-Hunton	Mis, Sil	SL	Por	10	A	33	Wilcox	4,330
66	x	x	Wilcox	Ord	S	Por	6	x	x	2d Wilcox	5,561
67	y	y	y	y	y	y	y	y	y	y	y
68	y	1.34	2d Wilcox	Ord	S	Por	46	AF	1	Lower Simpson	8,025
69	1,400	1.3	Burbank	Pen	S	x	70	AL	1	Wilcox	2,975
70	x	x	Lyons	Pen	S	Por	17	AF	2	Lyons	3,710
71	x	x	Trospex	Pen	S	Por	12	ML	3	Wilcox	6,904
72	1,180	0.8	Wilcox	Ord	S	22.5	120	AF	14	y	y
73	1,160	0.7	Lower Simpson	Ord	S	Por	140	AF	8		
74	1,150	0.7	Arbuckle	Cam, Ord	L	Cav	y	AF	7	Arbuckle	7,138
75	1,140	0.8	Cleveland	Pen	S	Por	y	A	1		
76			Misener	Pen	S	Por	9	ML	1		
77											
78	y	y	Senora-Calvin	Pen	S	Por	y	y	y	y	y
79	x	x	Layton	Pen	S	Por	24	A	4	Wilcox	4,675
80	y	y	Stalnaker-Oswego	Pen	SL	y	y	AF	11	Arbuckle	y
81	x	1	Papoose (Cromwell)	Pen	S	Por	10	A	x	Wilcox	x
82	x	x	Various	Pen-Ord	LS	Por	y	y	y	Arbuckle	y
83	x	x	Wilcox	Ord	S	Por	45	A	4	2d Wilcox	4,919
84	y	y	Various	Per-Mis-Ord	S	y	y	A	46	Arbuckle	y
85	y	y	Wilcox	Ord	S	Por	x	A	3	Wilcox	4,590
86	y	1	Pontotoc-Simpson	Per-Ord	SL	y	y	A, AU	37	Pre-Cambrian	1,745
87	y	y	Ada Form	Pen	LS	Por	35	x	4	y	600
88	y	y	Hunton-Simpson	Sil-Ord	LS	Por	y	y	y	y	y
89	y	y	Cromwell-Wilcox	Pen-Ord	S	Por	x	AF	17	Wilcox	4,300
90	y	y	Wilcox	Ord	S	Por	y	y	y	y	y
91	y	y	Booch	Pen	S	Por	y	y	y	y	y
92	y	y	Wilcox	Ord	S	Por	y	AF	y	y	y
93	y	y	Hunton-Wilcox	Sil-Ord	SL	Por	y	y	y	y	y
94	y	y	Wilcox	Ord	S	y	y	y	y	y	y
95	y	y	Wilcox (Simpson)	Ord	S	Por		A	142	2d Wilcox	4,860
96	y	y	y	y	y	y	y	y	y	y	y
97	x	4.8	Wilcox	Ord	S	Por	30	A	2	Wilcox	4,150
98	y	y	2d Wilcox	Ord	S	y	y	y	y	y	y
99	y	y	Earlsboro	Pen	S	Por	y	y	y	y	5,562
100	y	y	Deese	Pen	S	30	y	A	54	Dornick Hills	5,115
101	x	x	Wilcox	Ord	S	Por	6	A	0	Wilcox	4,306
102	x	x	Deese-Dornick Hills	Pen	S	30	60	AMU	36	Dornick Hills	4,250
103	y	y	Various	Pen, Mis Ord	SL	Por		AF	25	Arbuckle	y
104	y	y	Not Determined	?	L	Por	40	D	0		
105	1,335	3.13	Various	Pen-Ord	S	Por	x	AF	55	Arbuckle	4,415
106	y	y	Stalnaker	Mis	S	Por		A	8	Arbuckle	y
107	y	y	Simpson	Ord	S	Por		A	1	Simpson	1,251
108	x	x	Wilcox-Layton	Ord-Pen	S	Por	8–20	D	18	Arbuckle	4,508
109	y	y	Cromwell-Hunton-Wilcox	Pen, Sil, Ord	SL	Por		A	98	Wilcox	4,200
110	y	y	Pontotoc	Upper Pen	S	y	y	A	15	Pen	3,900
111	1,440	3	Hunton	Sil	L	x	50	A	0	Wilcox	4,520

SE.¼ of sec. 27, T. 22, R. 2 W, was drilling in an effort to extend the pool northeast.

Crescent Pool.—Very little development was undertaken in the Crescent pool in the year 1935; with nine producing wells being completed during the year. The pool has been curtailed by proration to about 5000 bbl. of oil per day.

Greater Seminole Area.—Greater Seminole area had an increase in production in 1935 over 1934, as several pools were permitted to flow to capacity most of the year. The Bowlegs, Fish, Keokuk Falls, Little River, East Little River, Maud, Sasakwa, Sasakwa Townsite, St. Louis-Pearson, Searight, Seminole and East Seminole pools showed increased production in 1935, while the Allen, Carr City, Cromwell, Earlsboro, Holdenville, Konawa, Mission and Wewoka pools showed a decrease. The Keokuk Falls pool underwent considerable development during the year.

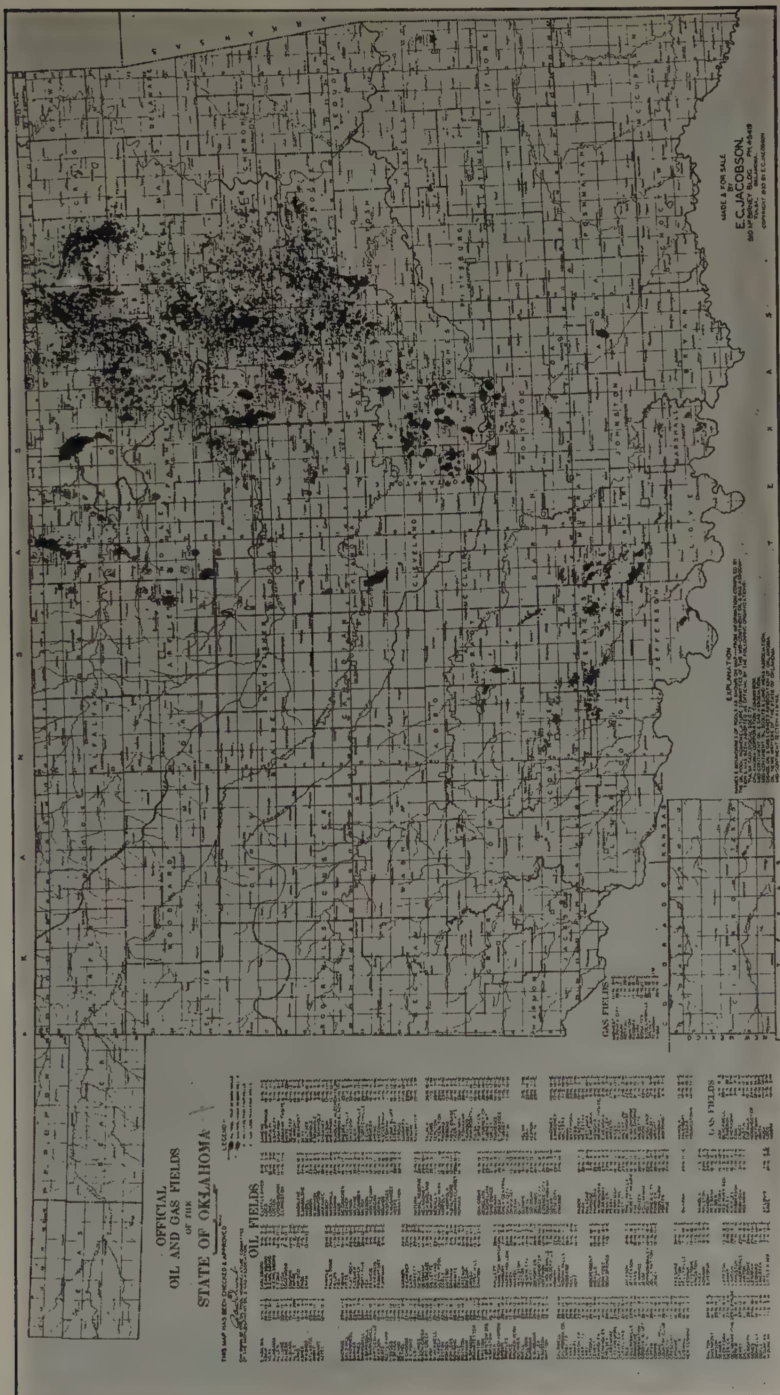
Oklahoma City Field.—The Oklahoma City Wilcox zone was extended about 2½ miles northward by the British American Green No. 1, and on Dec. 20, 1935 by well No. 1 Piersol of the same company, which came in flowing at the rate of 27,569 bbl. per day. The well was located just 675 ft. north of the Oklahoma Governor's Mansion and within 2500 ft. of the east wing of the Oklahoma State Capitol building. It has been suggested that this extension be called the "Mansion area." By the end of the year several wells with large initial production showed that this

TABLE 2.—*Summary of Drilling Operations in Oklahoma*

Important Wildcats Drilled in 1935

	County	Location			Total Depth, Ft.	Completion Date	Deepest Horizon Tested	Drilled By	Initial Production per Day
		Section	Township	Range					Oil, U.S. Bbl.
1	Carter	27	2 S.	3 W.	8,088	10–25	Simpson	Carter Oil Co.	10,000
2	Pontotoc	32	2 N.	6 E.	4,475	9–11	Wilcox	E. H. Moore et al.	19,200
3	Pontotoc	12	1 N.	7 E.	4,633	11–27	McLish	Continental Oil Co.	12,170
4	Oklahoma	23	12 N.	3 W.	6,360	10– 9	Wilcox	British American Oil Co.	2,400
5	Cleveland	21	10 N.	2 W.	7,291	6–26	2d Wilcox	Sinclair Prairie	Distillate
6	Seminole	13	6 N.	5 E.	3,816	2– 8	Simpson	Gulf Oil Corp.	624
7	Lincoln	5	14 N.	3 E.	5,084	2–22	Wilcox	Sinclair Prairie	180
8	Seminole	14	10 N.	6 E.	4,147	4– 3	Wilcox	Carter Oil Co.	1,091
9	Oklahoma	19	13 N.	3 W.	6,789	6–26	Wilcox	Slick Urschel	465
10	Hughes	12	9 N.	8 E.	1,735	7–31	Calvin	Olympic Oil	200
11	Payne	28	19 N.	3 E.	4,305	8–14	Wilcox	Amerada Petr. Corp.	587
12	Jackson	32	1 N.	19 W.	2,607	10– 2	Cisco lime	Gulf Oil Corp.	567

	In Proven Fields	Wildcats	Total
Number of wells drilling Dec. 31, 1935	340	65	405
Number of oil wells completed during 1935	1,430	39	1,469
Number of gas wells completed during 1935	113	5	118
Number of dry holes completed during 1935	559	174	733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OIL AND GAS FIELDS
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FIG. 1.

extension was of major importance. By April, 1936, approximately 100 drilling operations were being conducted in this north extension, or so-called "Mansion area." By a vote of the residents of the city, practically all of the area east of the Santa Fe tracks has been thrown open to development. It is expected that the Mansion area will be the most active spot in Oklahoma during the year 1936.

On the east side of the field several wells found abundant production in the Wilcox along the side of the fault line. Water soon appeared in these wells. Extension of the drilling zone within the city resulted in the completion of wells with large initial production. Pressure drilling was used with great success. Pumping equipment replaced gas-lift and other methods of production during the year.

Water-flooding and Gas Repressuring

Water-flooding Projects in Northeastern Oklahoma.—Water-flooding markedly increased in 1935. Many companies are carefully studying the results of the present projects under way. A number of water-flood projects were under way at the end of the year in Nowata, Rogers and Washington counties.

Water-flooding has been thoroughly approved by the industry. The Legislature of the State of Kansas in the spring of 1935 legalized the use of water in repressuring; likewise the Corporation Commission of the State of Oklahoma has issued permits for water-flooding under suitable circumstances.

The future of this method of recovery depends upon the solution of a number of technical problems. If operations are conducted on a scientific basis, the result will be in the interest of conservation and the stripper-well area of northeastern Oklahoma will enjoy a prolonged economic life.

Gas-repressuring Projects in Oklahoma.—A number of the pools in eastern Oklahoma were being repressured by the introduction of gas and the building up and restoring of formation pressure. A greater part of the Cromwell pool, located in Seminole and Okfuskee counties, has been repressured with much success. A number of properties in northeastern Oklahoma, notably in Osage County, have been repressured, in some cases with remarkable results, the production being increased many times over the production prior to repressuring.

The most successful repressuring operations have been carried out by the introduction of formation gas, or in some cases, dry gas, rather than the use of air.

Legislation

Well Spacing.—The passage of House Bill 187 by the State Legislature in April permitted the Oklahoma Corporation Commission to establish

well-spacing units in new oil pools. The Edmond, Jesse and Fitts-Upper Simpson pools established 10-acre spacing units under this law in 1935.

State Board of Professional Engineers.—On May 13, 1935, the Governor of the State of Oklahoma approved House Bill No. 264, which created a State Board of Professional Engineers and provided for the regulation of the practice of professional engineering within the State of Oklahoma. This statute requires engineers who practice professional engineering in the State of Oklahoma to be registered with the State Board of Professional Engineers.

South Burbank Unit Plan

Unitization of the South Burbank field was an interesting feature of the year. The unit block comprises about 2400 acres. The producing formation is now being repressured with more than 1,000,000 ft. of gas daily in an effort to maintain formation pressures. More gas will be returned to the formation under the present plan. Gas-oil ratio and bottom-hole pressure tests are taken at regular intervals to check the movement of the gas.

Acknowledgment

The authors desire to acknowledge the assistance of Mr. W. J. Armstrong, of the Corporation Commission of the State of Oklahoma, and the records and data made available through his courtesy; and the official nomenclature map supplied by Mr. E. C. Jacobson of Tulsa, Oklahoma.

The authors also acknowledge gratefully the assistance received from the following contributors: C. H. Pishney, Amerada Petroleum Corporation; R. B. Roark, Shell Petroleum Corporation; H. S. Thomas, Slick-Urschel Oil Co.; Don R. Gearheart, Sinclair-Prairie Oil Co.; Charles H. McNeese, Continental Oil Co.; C. G. Carlson, Geologist, Tulsa, Okla.; George Lang and L. F. McCollum, Carter Oil Co.; Harry H. Power, Gulf Oil Corporation; D. H. Thornton, Texas Company; L. L. Foley, Marathon Oil Co.; C. W. Tomlinson; B. H. Murphy, U.S. Geological Survey; John Van Dall, Magnolia Petroleum Co.; R. L. Clifton, Champlin Refining Co.; Hubert Bale; Merritt H. Brown, Darby Petroleum Corporation; John M. Alden, U.S. Geological Survey; H. W. Peabody, Mid-Continent Petroleum Corporation; and many others.

Oil and Gas Development in Northwestern Pennsylvania in 1935

By Norman E. Maxwell*

(New York Meeting, February, 1936)

There was more activity in crude production in northwestern Pennsylvania in 1935 than for several years before, resulting in an increased oil production and also in the number of wells completed. Crude production approximated 16 million barrels for the state, an increase of about one million barrels over 1934. Demand, indicated by refiners' runs to stills, increased proportionally, leaving stocks of available crude at the end of the year at the lowest point since the middle of 1934, when they reached an all-time low.

The price of crude varied during the year from a low of $2.02 to a high of $2.27 at the end of the year for Middle district oil. The price of Bradford and southwest Pennsylvania oil changed accordingly. The average for the year would be a lower price than in 1934.

A summary of the production data for the year 1935 is given in Table 1. In making up this table, 1935 figures were simply added to the table published by S. H. Cathcart last year[1]. A list of important wildcats is given in Table 2.

Bradford Field

Approximately 10,000 acres of the proven producing area of the Bradford field is in Cattaraugus County, New York, and it is possible, by differences, to distinguish the Pennsylvania production from the New York portion. The listed production for the Bradford field includes only that portion of the field situated in Pennsylvania, but also includes production from a small pool, locally known as the Mt. Jewett-Kanesholm pool, where the Bradford sand is being developed and flooded in precisely the same manner as that of the Bradford field itself. The Mt. Jewett-Kanesholm pool is not, strictly speaking, an extension of the Bradford field, but inasmuch as it is so closely allied with the Bradford field—that is, the sand is the same and the production methods are the same—the production and drilling figures include this area.

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* Crew Levick Co., Titusville, Pa.

[1] L. H. Cathcart: Oil and Gas Development in Pennsylvania, 1934. *Trans.* A.I.M.E. (1935) **114**, 365.

The 1935 production from the Pennsylvania end of the Bradford field included a total of 12,193,322 bbl., which is an increase of about 10 per cent over the 1934 production of 11,070,959 bbl., and, whereas the production increased only approximately 10 per cent over 1934 production, the total number of well completions increased approximately 15 per cent over the 1934 activities, indicating, at least partly, the fact that less productive areas are now being developed. The total number of well completions listed in the table includes the wells that have been drilled for water-intake wells and it is estimated that 45 to 50 per cent of the total number of well completions were oil wells and the remainder water-intake wells.

Bradford crude prices fluctuated between a low of \$1.95 and a maximum of \$2.30, with a weighted average price for the entire year of \$2.176 per barrel.

Some pipe line proration was in effect during 1935 and the ratable pipe line contracts varied from 75 to 100 per cent of their stipulated

TABLE 1.—*Oil and Gas Production in Northwestern Pennsylvania in* 1935

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1934[1]	During 1934[1]	During 1935[2]	Daily Average during Nov., 1935
1	*Clarion*	47–66	20,*xxx*	*x*	181,*xxx*	201,*xxx*	2,646,675	141,515		
2	*Crawford*	13–76	6,000	*x*	1,000	7,*xxx*	1,089,804	92,904		
3	*Elk*	10–53	12,427	*x*	99,*xxx*	111,*xxx*	1,274,958	74,923		
4	*Forest*	51–71	22,*xxx*	*x*	19,*xxx*	41,*xxx*	1,486,417	90,296	2,690,950	7,560
5	*Lawrence*	25–55	15,*xxx*	*x*	8,*xxx*	23,*xxx*	342,403	17,668		
6	*Venango*	48–76	84,*xxx*	*x*	44,*xxx*	128,*xxx*	16,435,232	902,195		
7	*Warren*	14–75	49,*xxx*			53,*xxx*	4,924,365	421,255		
8	Bradford, *McKean*	20–72	75,258	*x*	*x*	75,258	304,074,700	11,897,700	12,193,322	36,800
9										
10	*Potter*									
11	East Fork, *Potter*	3			200	200				
12	Ellisburg, *Potter*	2			1,600	1,600				
13	Genesee, *Potter*	3			500	500				
14	Harrison, *Potter*	2			*xxx*	*xxx*				
15	Hebron, *Potter*	4			4,*xxx*	4,*xxx*				
16	Farmington, *Tioga*	5			7,000	7,000				
17	Gaines, *Tioga*	37	200			200	48*x*,*xxx*	4,8*xx*	*y*	*y*
18	Sabinsville, *Tioga*	*y*			*y*	*y*	*y*	*y*	*y*	*y*
19	Total		285,*xxx*	*x*	365,*xxx*	652,*xxx*	332,274,554	13,638,456	14,88*y*,*yyy*	44,4*yy*

[a] Footnotes to column heads and explanation of symbols are given on page 215.
[1] From Pennsylvania Statistical Department.
[2] Figures for counties not available. Total production for district comprising these counties given.

quantities. A weighted average of this ratable call was almost 87.5 per cent.

No radical changes in methods occurred during the year, but there was a decided increase in emphasis on improvement of technic of flooding practice, which was reflected in the taking of a greater number of cores and a greater interest in water treatment.

Middle District

Production throughout the Middle district increased during 1935 as the result of drilling and repressuring begun in 1934, as is shown in the graph of Fig. 1. Further work has been done this year which undoubtedly will serve to increase production in this region. This district is composed of the following counties:

Warren County.—Considerable interest was shown in the water-flooding of the Clarendon sand. Five different projects have put about 150 acres of the field under test. Results are not determinable at this

Table 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1935		At End of 1935				
	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1935	To end of 1934[1]	During 1934[1]	During 1935	Maximum Daily during 1935	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[6]	Producing Gas Only	Total Producing
1	x	x	y	157,xxx	7,678	4,xxx	y	x	x[3] 59	x[3] 74	y	2,4xx	y	2,4xx	4,8xx
2	x	x	y					x	2y	x	y	1,4xx	y		1,4xx
3	x	x	y	73,xxx	2,982	3,xxx	y	x	y 2	x 4	y	1xx	1,2xx	y	1,4xx
4	x	x	y	14,xxx	590	5xx	y	x	y 1	x 3	y	1,3xx	3xx	y	1,6xx
5	x	x	y	1,62x	13	y	y	1,8xx 1xx	1x	1yy	y	6xx		5	6xx
6	x	x	y	59,xxx	2,755	3,xxx	y	x	2yy 10	y 1	y	22,5xx	58x	y	23,xxx
7	x	x	y	12,xxx	411	1xx	3	x	2yy	y	y	7,5xx	3xx	y	8,xxx
8				53,xxx	2,197	1,xxx	y	x							
9	4,06x	10x		y	y	y	y	x	2,550[4] 11	y 6	y	32,xxx	1,8xx		32,xxx
10															
11				79	62	y	y	2			y			2	2
12				448	448	12,1xx	y	29	22	3	y			2y	2y
13				y	y	0	y	2	y	y	y			y	y
14				0	0	2	y	3	2	y	y			3	3
15				34,579	15,361	14,622	y	33	3					32	32
16				35,171	10,258	4,607	y	47	3					44	44
17	1,5xx		y					1xx	y	y	y	5y			5x
18				y	y	y	y	y	3	y	y	y	y	y	y
19	x	x	y	438,yyy	42,yyy	43,yyy	y	y	3,xxx[3] 116	x[3] 95	y	67,xxx	4,1xx	2,5xx	73,xxx

[3] Upper figure applies to oil, lower to gas.
[4] Total oil and water intake wells. Oil wells are 45 to 50 per cent of total.

time, as the delayed method is used and only a few of the flood oil wells have been drilled.

Additional interest was shown in the Clarendon and Glade sands by numerous cores being taken for the determination of the proper secondary

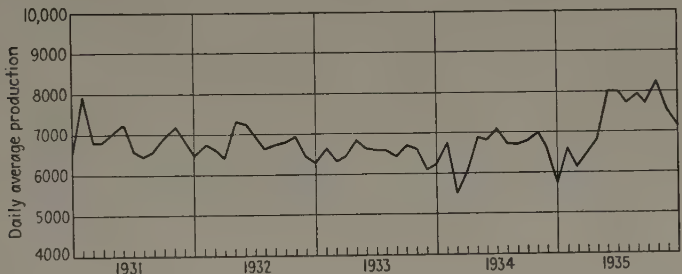

FIG. 1.

method of recovery and for valuation purposes. There was even more activity in the shallower Venango sand territory, in the southern part of

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935: Number of Wells: Flowing	Number of Wells: Pumping	Number of Wells: Air-lift	Injection into Reservoir[d]	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1934	Average at End of 1935	Character of Oil, Approx. Average during 1935: Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	y[3] 2,04y	y		All			y	Vac.	Vac.	y	y	y	y	P
2	980	800		All		GAW	y	Vac. to 10	Vac. 10			45	0.01	P
3	2,402	2,340		All			y	y	y	46	43	44	0.00	P
4	{ 700[3] 1,500	y		All		W	y	y	y	47	43	y	y	P
5	{ 690[3] 900	{ 650 900		All			{ 2xx[3] 250	{ y 50	{ y y	46	44	45	0.01	P
6	{ 420[3] 1,970	{ 400–950 y		All		GA	y	y	Vac. to 5	415	317	y	0.01	P
7	{ 900[3] 1,500	350 1,000		Balance	1x	GA W	600	y	y	y	y	42	0.01	P
8	1,500	1,500	y	All		W	y	y	y	y	y	43	0.01	P
9														
10							x,xxx	x,xxx	x,xxx					
11	6,220	6,200					2,025	2,025	1,506					
12	5,160	5,160					y	y	y					
13	4,850	4,850					2,240	2,125	2,110					
14	4,750	4,750					1,850	1,075	473					
15	5,215	5,200					1,650	900	450					
16	4,050	4,050		All			Low	y	y	y	y	44.0	y	P
17	1,000	982					y	y	y					
18	y	y												P
19														

Warren County. More wells were drilled and cored than in any previous period, the object being to determine, if possible, from the physical characteristics and composition of the sand, the best method of applying air or gas repressuring.

Considerable property was transferred, sales being made to both local operators and outside interests. Several new repressuring plants were erected and repair work was done on old leases.

A commercial attempt has been made to water-flood the First Venango sand.

Crawford County.—Producing acreage in this county is small, and represents extensions of pools from Venango County. The producing horizons are the Venango, First, Second and Third sands. Increased activity was shown in drilling and coring these sands, and in the application of air and gas repressuring.

Forest and Elk County.—Very little new work was done in these counties during 1935. A few wells were drilled and cleaned out, no wells

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1933: B.t.u. per Cu. Ft.	Character of Gas Approx. Average during 1933: Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Porosity[i]	Producing Rock: Net Thickness, Average Ft.	Producing Rock: Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Deepest Zone Tested to End of 1933: Depth of Hole, Ft.	Reference to Text[k]
1	*y*	40	[5]	MisL DevU	S	15 13	35 14	AMC	*x*	*y*	*y*	
2	*y*	*y*	Venango 3d	MisL	S Cgl	10–25	40	MLC	*x*	Queenston shale	4,619	
3	1,2*xx*	15	Kane	DevU	S	12	38	AMC	*x*	Queenston shale	7,930	
4	1,300	40	Various sands from Venango 1st to Cooper	DevU	S	17	20	AMC	*x*	Salina	5,252	
5	*y*	*y*	Berea to Venango 3d	MisL	S	16	10	AMC	5*xx*[3]	Helderberg	4,767	
6	1,300	40	Sands from Venango 1st to Speechley	MisL DevU	S Cgl	4–25	10–40	MLC	*x*	Queenston shale	4,619	
7		20	Sands from Venango 1st to Cooper	MisL DL	S Cgl	4–25	10–30	AMC	*x*	Queenston shale	5,818	
8	*y*	*y*	Bradford 3d	DevU	S	14.5	40	A	*y*	Medina	5,820	6
9												
10												
11	*y*	0.0	Oriskany	L Dev	S	*y*	20	A	0	150 ft. below Oriskany	6,437	7
12	*y*	0.0	Oriskany	L Dev	S	*y*	*y*	AF	1	Oriskany	5,160	7
13	*y*	0.0	Oriskany	L Dev	S	*y*	*y*	AF	1	Oriskany	4,850	7
14	*y*	0.0	Oriskany	L Dev	S	*y*	*y*	AF	0	Oriskany	4,750	7
15	*y*	0.0	Oriskany	L Dev	S	9–10	15	AF	12	Salina	5,561	7
16	1,030	0.0	Oriskany	L Dev	S	4–12	50	AF	40	Vernon shale	7,148	7
17			Atwell and Blossburg	U Dev	S, H	*y*	*y*	T	*x*	*y*	*y*	7
18			*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	7
19				Pen to L Dev								

[5] Various sands ranging from 1st Venango to Bradford.
[6] Data compiled by A. C. Simmons, Torrey Fralick & Simmons, Bradford, Pa.
[7] Gas data for 1935 supplied by J. G. Montgomery, Jr. United Natural Gas Co., Oil City, Pa

were pulled out or abandoned and on the other hand no wells were reclaimed or put back on production.

Clarion County.—Production activity in Clarion County was confined to the drilling of a few new wells, and preliminary work in the use of repressuring. This work was confined to the recycling of gas through the sand without detailed core studies being made or the use of definite drilling patterns for intensive repressuring, as is done in Warren and Venango counties. Information on the results of the programs is not available at this time.

Venango County.—Production activity experienced an increase during 1935 with interest in property and new work exceeding that shown in several years past.

Numerous wells were drilled and cored, both for the purpose of valuation and determination of the nature of the sand and oil content. Several new pressure plants were built and in some cases new powers were installed to handle the expected production. One interesting installation was that of an electric driven power, in conjunction with a Diesel-operated generator and compressor. The operation of this hook-up will be watched with interest by local operators.

Core studies of individual wells have been carefully made and have given the producers a much better conception of the sand and oil content than they previously had.

It appears from these studies that the oil content of the sands, and therefore the crude reserve of this district, is greater than estimated in the 1934 report. The thickness of the sands varies widely over this area, making an estimate of the average oil content difficult to ascertain.

A fair average of the cores taken shows an oil content of from 200 to 250 bbl. per acre-foot of sand.

Core analysis has brought to the minds of the operators the question of sand texture and its relation to ultimate recovery as well as the operating problems of pressures and volumes involved in the efficient repressuring of oil sands. These questions as yet are unanswered either from a

TABLE 2.—*Summary of Drilling Operations in Pennsylvania during* 1935*

Important Wildcats Drilled in 1935

	County	Location: Township	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day: Gas, Millions Cu. Ft.	Pressure, Lb. per Sq. In.: Tubing	Remarks
1	Beaver..	South Beaver	4546	Allegheny	Oriskany	John Galey et al.	1		
2	Tioga...	Clymer	4628	Chemung	Oriskany	East Penn Dev. Co.	5.9	2125	
3	Potter...	Allegany	5225	Chemung	Oriskany	Godfrey Cabot			No gas or water.

* By J. G. Montgomery, Jr., Oil City, Pa.

theoretical or practical standpoint, but their answer is to be the object of 1936 field and laboratory research.

Producers will be aided by the Research Department of Pennsylvania State College in cooperation with the Pennsylvania Grade Crude Oil Association in undertaking this particular problem.

Lawrence County.—There was little production activity in Lawrence County. Not over 10 wells were drilled and, in contrast to this, approximately 100 wells were pulled out; consequently crude production undoubtedly decreased. There are no immediate projects for applying secondary recovery methods in this field.

Acknowledgments

The author acknowledges the assistance of the following named in compiling this report: Oil City Derrick; Mr. C. C. Hogg, National Petroleum Co.; Mr. W. H. Young, Oil Core Testing Laboratory; Mr. A. C. Simmons, Torrey, Fralich and Simmons; Mr. J. G. Montgomery, Jr., United Natural Gas Company.

Oil and Gas Developments in Tennessee in 1935

By Walter F. Pond,* Member A.I.M.E., and Kendall E. Born,† Student Associate

(New York Meeting, February, 1936)

Production of crude oil in Tennessee during 1935 approximated 20,000 bbl., an increase of about 5000 bbl. over 1934. The total production for the state is an estimate, since the only definite figures available are those for Scott and Morgan counties, where 12,377 bbl. were marketed during 1935, an increase of 4305 bbl. over the preceding year.

The oil fields of Scott and Morgan counties are near the eastern margin of the Cumberland Plateau where Pennsylvanian sediments rest unconformably upon the Mississippian. Near Glenmary, in Scott County, the production is from the middle Mississippian, probably near the top of the St. Louis limestone. Accumulation is due to a low, east-west anticline which has been cut by a fault. This field is now 20 years old and only a few wells are pumped at present.

Oil was struck along Boone Camp Creek in Morgan County in 1924 and there has been small production since that time. The oil comes from the middle of the Fort Payne formation of lower Mississippian age at a depth of 1400 ft. Geologic work in the area has shown that a terrace and porosity conditions in the Fort Payne formation account for the accumulation.

The production figures on a number of small producing wells in Clay and Overton counties are not available. As pointed out by Glenn[1], the installation of small local skimming or topping plants in the fields has curtailed the shipment of crude oil out of the state and as a result it has been impossible to secure accurate production figures in these counties. The operators, in most cases, are reluctant to give information, and there is no state law requiring them to do so. Based upon information available to the writers, it is believed that between 7000 and 8000 bbl. is a fair estimate of the production in Clay and Overton counties during 1935.

More than 500 wells have been drilled in Clay County, the majority of which were drilled east of Cumberland River. Some eight small oil fields have been developed in the county within the past 12 years, a

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† Assistant Geologist, Tennessee Division of Geology.

[1] L. C. Glenn: *Trans.* A.I.M.E. (1934) **107**, 228.

number of which have been later abandoned. The entire production is from fissured and fractured Ordovician limestones of Lowville and Stones River ages. The conditions necessary for commercial accumulation in this area appear to depend largely upon the porosity, resulting from fractures and fissures in the limestone, and the presence of anticlinal structures. The average life of the wells has been from three to five years, depending largely upon the care of the well. Initial volumes of 1000 bbl. daily have not been uncommon, but as a rule this volume rapidly declines to a settled production of about 100 bbl. or less per day. At the end of six months the production commonly has dropped to 10 or 20 bbl. daily, and the production then slowly decreases during the next four or five years.

The only natural gas marketed off the lease in Tennessee occurs with the oil in Morgan County and is used to supply the town of Sunbright. Total gas-production figures for 1935 are not available at this time.

Development

During 1935 twenty wells were drilled in Tennessee for oil and gas, eight of which were begun late in 1934. Four of the 20 tests are still drilling or only temporarily shut down. Of the total wells drilled during the past year, three were producers, one of which was soon abandoned.

The acid process for treating wells was used during 1935 for the first time in Tennessee in the Scott and Morgan counties fields. During the past year 14 wells were treated with acid, including a new producer drilled during the year. In the acidizing of the 13 old wells, some of which were drilled in 1917, each responded to treatment with increases ranging from 100 to 500 per cent The new well increased approximately 100 per cent as a result of the acid treatment.

Since 1934 there has been renewed interest in the oil and gas possibilities of the Mississippi embayment region of western Tennessee. In the past two years 10 wells have been drilled in this area, six of which penetrated the Paleozoic floor for varying distances. Gas shows have been reported in some of the Upper Cretaceous sands, but thus far there has been no production. Pertinent subsurface data have been made available by these drilling operations and have been recently discussed by Born[2]. The thinning and wedging out of certain of the Upper Cretaceous formations towards the west, instead of thickening in that direction, is worthy of note. Data obtained from wells that penetrated the top of the Paleozoic rocks show the normal west dip or slope of the Paleozoic floor towards the west.

These recent tests in west Tennessee were located on surface structures or without regard to structural conditions. Since in a region of

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[2] K. E. Born: Notes on the Upper Cretaceous and Tertiary Sub-Surface Stratigraphy of Western Tennessee. *Jnl.* Tenn. Acad. Sci. (1935) **10**, 248–264.

essentially unconsolidated sands, clays, and gravels, surface indications have little or no value in the determination of subsurface conditions, the Mississippi embayment area in Tennessee offers a fertile field for careful geophysical work. It is encouraging to know that within the past year some geophysical work has been carried on by private interests. A well now drilling in Tipton County, just north of Memphis, is reported to be located on a seismic high.

Interest persists in the gas possibilities in middle Tennessee. Since 1930 three or four small gas wells have been drilled in eastern Dickson County, some 35 miles west of Nashville. These wells obtained initial gas volumes as great as 100,000 cu. ft., but the rock pressure is low. The gas occurs in fissured limestones near the top of the Ordovician (Leipers and Fernvale). At present these wells are capped, awaiting development.

Several years ago a number of gas wells were drilled in Macon County on the northern Highland Rim. One of these tests was reported to have encountered 27 gas horizons in a vertical distance of 400 ft. and a reported initial flow of more than a million cubic feet. In Macon County the gas occurs in shaly limestone horizons of Ordovician age at depths of a few hundred feet. Recent structural work, carried on by private interests, indicates that the gas accumulation has resulted from a number of small low anticlines and domes. Although these wells are believed to have penetrated commercial reservoirs of gas, there has been no production. At the present time there are reported plans to resume drilling operations in this region in an effort to develop the field.

During the last three years the three small gas fields that supplied the towns of McMinnville, Fayetteville and Cookeville, have been abandoned.

A number of inquiries have recently come to this Division relative to data available on the "St. Peter" horizon in Tennessee, and a well will be spudded in in the near future in Sumner County, north of Nashville, to test this horizon. In middle Tennessee a sandy horizon has been noted in a number of the deeper tests. Stratigraphically, this horizon lies at depths ranging from 1200 to 1500 ft. below the Chattanooga black shale. Cuttings from this interval consists essentially of well rounded, glassy or frosted quartz grains in a matrix of white, granular, somewhat magnesian limestone. This horizon has been questionably correlated by Bailey[3] with the St. Peter sandstone of the upper Mississippi Valley. Based upon our present information this correlation appears to be justified. The thickness of the "St. Peter" horizon averages 5 to 10 ft., but in a well drilled in Wayne County, in the southern part of the western Highland Rim, a 126-ft. interval has been tentatively correlated with the "Big Buffalo" series.

[3] W. F. Bailey: Notes on the Sub-Surface Stratigraphy of Middle Tennessee. *Jnl.* Tenn. Acad. Sci. (1931) **6,** No. 2, 82.

Immediately below the "St. Peter" horizon in middle Tennessee is a thick section of white, dense to crystalline, magnesian limestones, undoubtedly correlative in part with the "Knox" dolomite of eastern Tennessee. A well now drilling in southern Decatur County, in the western valley of the Tennessee River, will test the possibilities of the lower Ordovician and "Knox" dolomite of this region.

A great amount of difficulty has been encountered in correlating well cuttings from the lower Ordovician of middle Tennessee, and an insoluble-residue project has been begun by this Division in an effort to obtain characteristic horizon markers to aid in these correlations.

Since the Middle Devonian ("Corniferous") has long been a productive horizon in Kentucky, rocks of that age have been considered a possibility in middle Tennessee west of the Nashville dome. During the past summer a well, drilled on structure in central Dickson County, passed through some 12 ft. of Jeffersonville ("Pegram") limestone that was partly saturated with oil. Lithologically, this horizon is a coarsely crystalline limestone, with little porosity, but acidizing possibilities are suggested.

Petroleum in the Central Texas Area during 1935

By R. B. Kelly,* Member A.I.M.E., and Paul R. Martin†

(New York Meeting, February, 1936)

Central Texas added 76 producing oil and gas wells during the year, abandoned 378 wells in the same period, and produced 10,359,905 bbl. of oil in the 12 months under consideration. The oil production represents a decline of only 3 per cent as compared to 1934, but it must be remembered that much new production was added during the year. The activity in new work centered in Frio, Bexar, Williamson and Caldwell counties, with development in the Pearsall, Von Ormy and Byersville fields taking first importance. New discoveries in 1935 were confined to Pearsall area of Frio County and an extension to the Darst Creek field in Guadalupe County. The Red Lake field, in eastern Freestone County, proved itself of importance from the standpoint of a gas reserve but no oil production has yet been obtained. In Bexar County, the Von Ormy field, in which the discovery well was drilled early in 1934, completed 22 oil producers during the year. (A map of Central Texas showing location of oil and gas fields was published in Volume 114 of the A.I.M.E. Transactions.)

New Fields

Pearsall.—The Amerada Petroleum Corporation, in developing its 60,000-acre block in Frio County, has definitely proved the existence of commercial oil production in four separate horizons; namely, the Navarro, the Austin Chalk, the Buda and the Georgetown. The discovery well, a two million cubic foot gas well, was completed in 1934. A test of the Trinity sand at 10,050 ft. found salt water but later was plugged back and finished as an oil well in the Navarro sand. Most recent of their discoveries has been in the Austin Chalk at a depth of 5666 ft., where a 24-hr. gage through 1-in. choke showed 2640 bbl. of pipe line oil. The oil has a gravity of 28.0° A.P.I. and is brownish in color. Because of lack of pipe lines in the area, the wells are produced only for short periods of time, and it is predicted that development will be slow until the district is entered by pipe line purchasing companies.

Von Ormy.—In March, 1934, Umbren et al. completed their Wentz

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TABLE 1.—*Oil and Gas Production in Central Texas during 1935*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres			Total Oil Production, Bbl.
			Oil	Gas	Total	To End of 1935
1	Corsicana, *Navarro*	39	2,400	0	2,400 (300)	4,798,480
2	Mildred (Elm Ridge), *Navarro*	35	2,500	0	2,500 (500)	5,808,123
3	South Bosque, *McLennan*	33	2,500	0	2,500	84,450
4	Somerset, *Atascosa and Bexar*	23	11,390	0	11,390	9,638,270
5	Gas Ridge, *Bexar*	23	60	300	360 (200)	59,649
6	Thrall, *Williamson*	21	475	0	475 (500)	2,370,882
7	Angus-Edens-Hodge, *Navarro*	20	900	0	900	1,548,282
8	Burke, *Navarro*	20	250	0	250	235,930
9	Alta Vista[1], *Bexar*	20	300	0	300	102,480
10	Rice-Oil Ridge, *Navarro*	19	660	0	660	1,139,400
11	Mexia, *Limestone*	15	3,920	0	3,920	93,923,704
12	Minerva-Rockdale, *Milam*	14	4,000	0	4,000	3,177,769
13	Luling, *Caldwell and Guadalupe*	14	2,130	0	2,130	63,191,139
14	Yturri-Southton, *Bexar*	14	500	0	500 (10)	561,132
15	Chilton, *Falls*	13	40	0	40	91,070
16	Currie, *Navarro*	13	475	0	475 (150)	6,664,620
17	Ina, *Medina*	13	310	0	310	144,766
18	Powell, *Navarro*	12	2,600	0	2,600 (450)	106,915,279[12]
19	Adams, *Medina*	11	0	2,000	2,000 (60)	0
20	Richland, *Navarro*	11	440	0	440	6,605,490
21	Woodbine Area—Shallow Field (Powell), *Navarro*	11	750	0	750	3,762,100[13]
22	Bains Creek, *Limestone*	11	0	60	60	0
23	Taylor, *Medina*	11	30	0	30	27,374
24	Lytton Springs, *Caldwell*	10	1,360	0	1,360 (70)	7,924,664
25	Wortham, *Freestone and Limestone*	10	715	0	715	22,430,927
26	Chittam, *Maverick*	9	0	320	320	0
27	Dale, *Caldwell*	8	175	0	175	1,250,548
28	Eckert, *Bexar*	8	640	80	720	659,014
29	Salt Flat, *Caldwell*	8	1,195	0	1,195	33,609,169
30	Larremore, *Caldwell*	8	50	0	50	228,690
31	Yost, *Bastrop*	7	97	0	97	845,359
32	Cow Hill, *Zavalla*	7	0	1,000	1,000	0
33	Darst Creek, *Guadalupe*	7	1,670	0	1,670	35,365,518
34	Buchanan, *Caldwell*	7	75	0	75	169,274
35	Chapman, *Williamson*	6	560	0	560	3,850,389
36	Cooksey, *Bexar*	6	50	0	50	65,542
37	Manford, *Guadalupe*	6	30	0	30	359,930
38	Schimmel-Batts, *Bastrop*	5	50	0	50	4,224
39	Dunlap, *Caldwell*	5	70	0	70	240,699
40	Branyon, *Caldwell*	5	50	0	50	84,256
41	Chicon Lake, *Medina*	5	350	75	425	16,462
42	Carroll, *Bastrop*	3	40	0	40	29,555
43	North Dale, *Bastrop*	3	250	0	250	361,530
44	Hilbig, *Bastrop*	3	250	0	250	798,412

[1] Austin chalk producing horizon depleted.
[12] Net Woodbine production only.
[13] Production estimated due to shallow and Woodbine wells pumping to same tanks

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.			Average Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935 Completed	During 1935 Abandoned
1	112,205	111,690	304	1,999	0.7	0	0	0	0	1,280	0	8
2	23,725	6,025	17	2,323	0.81	0	0	0	0	1,270	0	235
3	6,570	3,480	12	34	0.4	0	0	0	0	123	0	7
4	260,775	267,385	726	846	0.99	0	0	0	0	1,048	2	12
5	4,220	2,589	7	994	1.0	8,301	170	131	0.5	120	0	13
6	19,800	16,920	47	4,991	4.7	0	0	0	0	15	0	3
7	7,200	7,030	22	1,720	0.63	0	0	0	0	205	0	2
8	25,800	25,550	60	944	1.2	0	0	0	0	85	0	0
9	2,160	1,820	5	342	0.5	0	0	0	0	41	0	0
10	8,760	14,965[14]	40	1,726	0.8	0	0	0	0	95	0	9
11	781,518	801,586	2,167	23,960	8.5	0	0	0	0	550	0	16
12	80,688	79,442	215	794	0.59	0	0	0	0	575	0	6
13	2,086,495	2,013,097	5,409	29,667	11.81	0	0	0	0	544	0	2
14	27,915	24,371	71	1,122	0.81	0	0	0	0	138	3	0
15	2,160	710	2	2,277	2.0	0	0	0	0	3	0	0
16	56,053	50,067	123	14,031	8.2	0	0	0	0	54	0	1
17	2,300	2,116	7	467	1.0	0	0	0	0	31	0	6
18	884,491	812,208	2,167	41,122	18.06	0	0	0	0	741[18]	0	6
19	0	0	0	0	0	11,469	360	348	1.5	46	0	1
20	13,150	10,740	14	15,012	4.67	0	0	0	0	107	0	0
21	40,680[13]	38,160[13]	84	5,016[13]	3.5	0	0	0	0	237[19]	2	4
22	0	0	0	0	0	x	38.	22	0.6	5	0	0
23	2,190	1,710	4	912	2.0	0	0	0	0	6	0	0
24	161,072	142,345	379	5,827	2.45	0	0	0	0	298	3	6
25	39,066	35,716	95	31,372	13.57	0	0	0	0	322	0	7
26	0	0	0	0	0	4,599.8	792.1	745	3.8	5	0	0
27	90,795	64,788	159	7,146	5.89	0	0	0	0	42	3	2
28	148,349	118,124	277	1,030	2.77	3,215	350	220	0.7	135	5	4
29	1,639,098	1,505,883	4,036	28,125	20.59	0	0	0	0	353	0	13
30	14,890	17,835	50	4,574	8.33	0	0	0	0	13	1	0
31	29,795	26,066	60	8,715	7.5	0	0	0	0	14	0	0
32	0	0	0	0	0	555.9	131.4[16]	27.4	0.8	7	0	0
33	3,321,976	3,285,033	9,188	21,177	38.28	0	0	0	0	261	0	3
34	16,875	13,789	37	2,257	7.4	0	0	0	0	6	0	1
35	178,850	143,004	334	6,876	4.39	0	0	0	0	112	2	2
36	9,000	6,137	20	1,311	1.67	0	0	0	0	15	0	2
37	17,898	13,204	37	11,998	18.5	0	0	0	0	4	0	1
38	600	624[15]	0	84	0	0	0	0	0	6	3	0
39	10,950	16,484	25	3,438	3.57	0	0	0	0	8	2	0
40	10,685	10,343	42	1,685	8.4	0	0	0	0	5	3	0
41	7,300	5,662	18	47	0.86	648.7	61.2	50	0.3	28	2	1
42	8,750	19,405	36	485	9.0	0	0	0	0	4	2	0
43	193,589	90,655	212	1,446	13.25	0	0	0	0	17	0	1
44	282,280	277,827	716	3,194	59.67	0	0	0	0	12	0	0

[b] Footnotes to column heads and explanation of symbols are given on page 215.
[14] Production increased due to better information.
[15] Produced 5 months, shut in 7 months during 1935.
[16] Shut in during February, March, and April, 1935.
[18] Does not include any shallow wells.
[19] Includes 55 wells recorded as Woodbine wells with casing ripped to produce shallow oil.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells, At End of 1935: Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Flowing	Pumping	Injection into Reservoir[d]	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1934	1935	Character of Oil, Approx. Average during 1935, Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	4	435	0	439	1,260	800	0	435	0	x	x	x	37.1	35.9	36.6	0.3	P
2	0	21	0	21	1,250	740	0	21	0	x	x	x	25 20[23]	21 18[23]	23 19[23]	0.6	P
3	0	30	0	30	475	450	0	30	0	x	x	x	42	40	41	0.2	P
4	30	735	0	765	2,100	1,400	0	735	0	x	x	x	39.4	34.4	36.4	1.4	P
5	0	7	50	57	830[20] 280[21]	780[20] 230[21]	0	7	0	220	135	128	23	21	22	0.4	P
6	0	10	0	10	1,000	700	0	10	0	x	x	x	37.6	36.4	37	0.3	P
7	5	35	0	40	1,185	740	0	35	0	x	x	x	36.5	35	36	0.6	P
8	10	50	0	60	480	400	0	50	0	x	x	x	21	21	21	0.8	P
9	2	10	0	12	250	220	0	10	0	x	x	x	36	34	35	0.3	P
10	6	50	0	56	1,000	960	0	50	0	x	x	x	36.4	35.2	35.7	0.4	P
11	14	255	0	269	3,085	3,000	0	255	0	x	x	x	36	34	35	0.3	P
12	26	364	0	390	1,700	600	0	364	0	x	x	x	40	36	38	0.2	P
13	25	458	0	483	2,200	2,100	0	458	0	x	x	x	28	26	27	0.9	A
14	10	88	0	98	800	600	0	88	0	x	x	x	33	31	32	0.5	P
15	0	1	0	1	1,160	1,080	0	1	0	x	x	x	33	31	32	0.8	P
16	0	15	0	15	2,990	2,930	0	15	0	x	x	x	41	40	40	0.2	P
17	0	7	0	7	960	940	0	7	0	x	x	x	19	19	19	0.7	A
18	9	120	0	129	3,000	2,925	0	120	0	x	x	x	38	36	37	0.3	P
19	0	0	20	20	1,000	900	0	0	0	400	120	115			Gas only		
20	0	3	0	3	3,040	2,975	0	3	0	x	x	x	38	38	38	0.3	P
21	4	24	0	28	850	1,650	0	24	0	x	x	x	34.8	23.5	33	0.4	P
22	2	0	0	2	2,960	2,945	0	0	0	875	210	180			Gas only		
23	0	2	0	2	400	290	0	2	0	x	x	x	18	18	18	0.4	P
24	20	155	0	175	1,900	1,600	0	155	0	x	x	x	39	37	38	0.4	P
25	0	7	0	7	3,050	2,990	0	7	0	x	x	x	38.6	36.2	37.3	0.2	P
26	0	0	3	3	5,590	5,525	0	0	0	2,200	1,240	1,210			Gas only		
27	10	27	0	37	2,250	1,915	0	27	0	x	x	x	38	36	37	0.2	P
28	16	100	5	121	670[20] 790[21]	655[20] 620[21]	0	100	0	200	148	134	35	33	34	0.3	P
29	20	196	0	216	2,740	2,670	0	196	0	x	x	x	36	36	36	0.6	P
30	0	6	0	6	1,315	1,285	0	6	0	x	x	x	23	23	23	0.2	P
31	0	8	0	8	1,500	1,335	0	8	0	x	x	x	28	26	27	0.3	P
32	0	0	7	7	800	675	0	0	0	295	225	210			Gas only		
33	16	240	0	256	2,700	2,650	0	240	0	x	x	x	37	35	36	0.8	P
34	0	5	0	5	2,075	1,750	0	5	0	x	x	x	37	35	36	0.2	P
35	10	76	0	86	1,915	1,730	0	76	0	200	100	90	36.7	35.2	36	0.2	P
36	0	12	0	12	1,460	1,440	0	12	0	x	x	x	34	32	33	0.4	P
37	0	2	0	2	2,320	2,260	0	2	0	x	x	x	37.3	36.7	37.3	0.9	P
38	6	0	0	6	1,900	1,400	0	0	0	x	x	x	34.8	33.8	34.4	0.2	P
39	0	7	0	7	2,300	2,290	0	7	0	x	x	x	37	35	36	0.6	P
40	0	5	0	5	2,000	1,900	0	5	0	x	x	x	38	36	37	0.8	P
41	0	21	6	27	495[20] 320[21] 810[21]	480[20] 240[21] 760[21]	0	21	G4	420	210	200	22[24] 36[25]	20[24] 34[25]	21[24] 35[25]	0.1	P
42	0	4	0	4	2,378	2,300	0	4	0	x	x	x	36	36	36	0.2	P
43	0	16	0	16	2,160	2,025	0	16	0	x	x	x	38	36	37	0.3	P
44	0	12	0	12	2,575	2,450	12	0	G1	1,240	1,086	1,035	37.2	37.2	37.2	0.2	P

[20] Gas.
[21] Oil.
[23] Both light and heavy oil, same horizon, paraffin base.
[24] Shallow.
[25] Deep.

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-Dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Depth of Hole, Ft.
1	1,040	1.8	Nacatoch, Corsicana	CreU	Ss	13–19	15	AF, AM	118	Woodbine sand	3,408
2	1,040	1.7	Nacatoch, Corsicana, Taylor and Navarro	CreU	Ss	14–20	16	AF, AM	300	Woodbine sand	3,570
3	1,225	2.0	Basal Walnut	CreL	DL	22	3	AF	100	Basal Trinity	1,800
4	*x*	*x*	Taylor, Navarro	CreU	SH	22	30	TF	75	Trinity sand	5,311
5	1,120	0.5	Taylor sand	CreU	S SH	15–20	15	A	39	Glenrose limestone	2,250
6	*x*	0.8	Serpentine	CreU	P	20–30	*x*	Intn.	23	Trinity sand	3,290
7	1,040	2.8	Nacatoch, Corsicana	CreU	Ss	12–18	18	AF, AM	65	Woodbine sand	3,335
8	1,040	*x*	Nacatoch sand	CreU	Ss	12–18	11	A	25	Woodbine sand	3,356
9	1,135	*x*	Navarro sand	CreU	S	15–20	23	F	28	Trinity sand	4,535
10	1,040	1.9	Nacatoch sand	CreU	Ss	12–17	12	AF, AM	28	Woodbine sand	3,086
11	1,152	2.5	Woodbine sand	CreU	SH	25±	50	F	145	Trinity sand	6,116
12	*x*	2.5	Upper Navarro	CreU	S	16	15	F	44	Edwards limestone	5,000
13	955	1.5	Edwards limestone	CreL	L	5–30	100	F	78	Schist	7,859
14	*x*	1.8	Navarro sand	CreU	S	16	10	F	34	Glenrose limestone	3,850
15	*x*	2.1	Georgetown limestone	CreL	LS	23	5	AF	23	Glenrose limestone	2,025
16	1,040	2.5	Woodbine sand	CreU	SH	22	20	F	52	Woodbine sand	3,300
17	*x*	*x*	Escondido sand	CreU	SH	*x*	15	F	34	Edwards limestone	2,048
18	1,080	2.5	Woodbine sand	CreU	SH	25	45	F	68	Trinity sand	6,506
19	999	2.3	Escondido sand	CreU	S	*x*	20	F	12	Edwards limestone	2,289
20	1,060	2.5	Woodbine sand	CreU	SH	25	20	F	23	Glenrose limestone	5,415
21	*x*	*x*	Sands in Taylor and Navarro	CreU	Ss	14–20	15	AF	50	Trinity sand	6,506
22	1,040	0.4	Woodbine sand	CreU	SH	20	15	F	9	Woodbine sand	3,208
23	*x*	1.4	Taylor sand	CreU	SH	15	15	Crev., F	15	Edwards limestone	1,285
24	1,040	1.5	Serpentine	CreU	P	14	*x*	Intn.	45	Edwards limestone	2,292
25	1,080	2.5	Woodbine sand	CreU	SH	25	35	F	63	Glenrose limestone	4,825
26	1,020	4.6	Glenrose limestone	CreL	L	*x*	50	A	8	Basal Trinity sands	7,635
27	*x*	1.5	Serpentine	CreU	P	15	*x*	Intn.	8	Edwards limestone	2,661
28	1,140	1.8	Navarro	CreU	S	16	10	F	14	Edwards limestone	1,590
29	*x*	2.5	Edwards limestone	CreL	L	30	30	F	36	Edwards limestone	2,918
30	1,120	1.3	Edwards limestone	CreL	L	*x*	35	F	7	Glenrose limestone	2,150
31	*x*	1.4	Serpentine	CreU	P	15–25	*x*	Intn.	8	Austin chalk	2,066
32	1,015	0.2	Escondido sand	CreU	SH	*x*	20	A	10	Glenrose limestone	4,709
33	*x*	2.3	Taylor marl, Austin chalk cavities, Edwards limestone	CreL	L	26	30	F	22	Edwards limestone	3,200
34	*x*	1.6	Serpentine	CreU	P	12	*x*	Intn.	3	Edwards limestone	2,483
35	1,025	0.8	Serpentine	CreU	P	20	*x*	Intn.	47	Edwards limestone	3,226
36	*x*	0.3	Taylor sand	CreU	S	13	10	F	7	Edwards limestone	2,250
37	*x*	1.5	Edwards limestone	CreL	L	35	30	F	4	Edwards limestone	2,800
38	1,120	1.5	Serpentine	CreU	P	13	*x*	Intn.	8	Austin chalk	2,001
39	*x*	1.5	Austin chalk	CreU	C	*x*	10	F	9	Edwards limestone	2,420
40	*x*	1.5	Crevice, Top Austin	CreU	C	*x*	*x*	F	8	Edwards limestone	2,450
41	1,095	0.5	Navarro, Taylor[24] Serpentine[25]	CreU	S[24] P[25]	13	*x*	D	13	Edwards limestone	1,725
42	1,025	2.5	Serpentine	CreU	P	12	*x*	Intn.	3	Edwards limestone	2,919
43	*x*	1.5	Serpentine	CreU	P	15	*x*	Intn.	14	Edwards limestone	2,950
44	1,300	1.0	Serpentine	CreU	P	12	*x*	Intn.	5	Serpentine	2,715

No. 1, central Bexar County, for an initial production of 10 bbl. per day. The past year saw 22 additional wells drilled in the field, which is now proven to the extent of approximately 400 acres. Several sands in the Midway and Taylor formations between 500 and 730 ft. yield oil. Production from the 28 wells at the close of the year was 79 bbl. per day, averaging less than 3 bbl. per well.

Red Lake.—The Woodbine sand in eastern Freestone County has yielded what appears to be an important gas field, although only two producing wells have been completed by operators, the Daniels Oil and Royalty Co. That company finished its No. 1 Ball on April 26, 1934, for an estimated 3 million cubic feet gas daily with 1800 lb. closed-in pressure. The Lone Star Gas Co. has now provided a connection for one well, the other producer being closed in. With a market for the gas, it is likely that additional wells will be drilled and some idea of the producing limits of the structure obtained.

Darst Creek Extension.—On July 28, 1935, Doody Oil Company's No. 1 Mrs. Katy Ray was completed for a 340-bbl. well at 2444 ft. in a crevice of the Austin Chalk. This well is one mile south of the main Darst Creek pool but is generally conceded to be on a separate structure,

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres			Total Oil Production, Bbl.
			Oil	Gas	Total	To End of 1935
45	Cedar Creek, *Bastrop*	3	160	0	160	177,737
46	Byersville, *Williamson*	2	360	0	360	239,114
47	Pearsall-Georgetown, *Frio*	2	0	160	160	0
48	Von Ormy, *Bexar*	2	400	0	400	15,900
49	Red Lake, *Freestone*	1½	0	x[11]	x	0
50	Manda, *Travis*	1¼	40	0	40	11,067
51	Pearsall-Upper Sand, *Frio*	1	400	0	400	8,600
52	Darst Creek Extension, *Guadalupe*	5 mo.	40	0	40	6,435
53	Pearsall-Buda, *Frio*	4 mo.	40	0	40	15,899
	Depleted Fields—Chronologically as to Discovery Date					
		Life				
54	Chatfield[2], *Navarro*	5 yr.	0	150	150	0
55	Mission[3], *Bexar*	16 yr.	200	0	200	63,000
56	Witherspoon-McKie[4], *Navarro*	20 yr.	400	0	400	810,495
57	Kosse[5], *Limestone*	8 dy.	10	0	10	33,000
58	Nigger Creek[6], *Limestone*	5 yr.	170	0	170	2,998,810
59	Cedar Creek[7], *Limestone*	4 yr.	30	0	30	297,945
60	Ottine[8], *Gonzales*	6 mo.	10	0	10	12,000
61	Lytton Springs Townsite[9], *Caldwell*	6 yr.	50	0	50	6,273
62	Marlin-Satin[10], *Falls*	3 yr.	10	0	10	1,560
63	Total		46,627	4,145	50,772	423,842,386

[2] Discovered 1905; depleted 1910.
[3] Discovered 1912; depleted 1928.
[4] Discovered 1915; depleted 1935.
[5] Discovered 1922; depleted 1922.
[6] Discovered 1926; depleted 1931.
[7] Discovered 1927; depleted 1931.
[8] Discovered 1929; depleted 1929.
[9] Discovered 1930; depleted 1935.
[10] Discovered 1932; depleted 1935.
[11] Limits of field not defined.

as a number of dry holes have been completed between the two areas. To date three producing wells have been completed but the limits of the field are still undetermined. The fact that three dry holes have been drilled indicates that the areal extent of the production may be small.

Exploration

Efforts in 1935 to obtain production in counties not heretofore productive failed except in Frio, mentioned above in detail. Two important tests in Kimble County, one to 4090 ft. in pre-Cambrian and the other to 4857 ft. in Ellenberger, were completed as dry holes. Hill and Bandera counties likewise failed to get into the producing column by abandonment of wells drilled to the schist.

On Dec. 31, 1935, there were 28 "wildcat" tests being drilled in the Central Texas area. During the year 98 failures were recorded in the same classification; while, bordering on or adjacent to proven fields, there were 63 additional dry holes completed.

Oil Recovery

During 1935 the 3726 wells in Central Texas averaged 7.6 bbl. per day as compared to 7.9 bbl. per day in 1934. Total recovery to date from

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.			Average Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935 Completed	During 1935 Abandoned
45	135,000	27,237	44	1,111	4.4	0	0	0	0	14	0	4
46	36,500	192,614	312	535	10.4	0	0	0	0	30	12	0
47	0	0	0	0	0	106	106	0[17]	0	1	0	0
48	1,992	13,908	79	40	2.8	0	0	0	0	37	22	0
49	0	0	0	0	0	315	0	315	1.5	2	1	0
50	440	10,627	48	279	24.0	0	0	0	0	3	0	0
51	0	8,600	0	21.5	0	0	0	0	0	4	4	0
52	0	6,435	45	161	15.0	0	0	0	0	3	3	0
53	0	15,899	150	397	150.0	0	0	0	0	1	1	0
			Depleted Fields—Arranged Chronologically as to Discovery Date									
54	0	0	0	0	0	4,750	0	0	0	15	0	0
55	0	0	0	315	0	0	0	0	0	32	0	0
56	3,960	340	0	2,026	0	0	0	0	0	85	0	40
57	0	0	0	3,300	0	0	0	0	0	1	0	0
58	0	0	0	17,640	0	0	0	0	0	75	0	0
59	0	0	0	9,932	0	0	0	0	0	14	0	0
60	0	0	0	1,200	0	0	0	0	0	1	0	0
61	183	10	0	125	0	0	0	0	0	3	0	1
62	1,200	440	0	156	0	0	0	0	0	2	0	1
63	10,804,605	10,359,905	28,383			33,960.4	2,009.1	1,858.4		9,309	76	378

[17] Shut in during all of 1935.

46,627 proven acres has averaged 9090 bbl. per acre, while the drilling density has averaged a well to each five acres.

It is interesting to note that in the past 10 years only three fields of major importance have been discovered in the district—Salt Flat, Darst Creek and Wortham. None of these fields will be likely to exceed an ultimate production of 60 million barrels. It is possible that the new Pearsall discovery in Frio County may enter this class, but what the future holds for this area is yet unpredictable.

Listed in their order of importance, based on expected ultimate oil recovery in excess of 10 million barrels, fields in Central Texas rank as follows:

	Field	County	Age	Producing Formation
1	Powell	Navarro	12	Woodbine
2	Mexia	Limestone	15	Woodbine
3	Luling	Caldwell-Guadalupe	14	Edwards
4	Darst Creek	Guadalupe	7	Edwards
5	Salt Flat	Caldwell	8	Edwards
6	Wortham	Freestone	10	Woodbine
7	Somerset	Bexar-Atascosa	23	Taylor
8	Pearsall (?)	Frio	2	Various

Only Powell and Mexia will produce more than 100 million barrels.

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells				Average Depth, Ft.		Oil Production Methods at End of 1935			Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935				
	At End of 1935						Number of Wells				Average at End of		Gravity A.P.I. at 60° F.				
Line Number	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Injection into Reservoir[d]	Initial	1934	1935	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
45	0	10	0	10	1,700	1,650	0	10	0	x	x	x	34	34	34	0.2	P
46	0	30	0	30	900	850	0	30	0	x	x	x	37	37	37	0.2	P
47	1	0	0	1	6,459	6,400	0	0	0	2,120	x	x			Gas only		
48	5	28	0	33	730	500	0	28	0	x	x	x	34[26]	34	34	0.4	P
49	1	0	1	2	4,855	4,820	0	0	0	x	1,968	1,968			Gas only		
50	0	2	0	2	757	720	0	2	0	x	x	x	34	34	34	0.4	P
51	4	0	0	4	3,935	3,920	4[22]	0	0	1,450	0	1,450	26	26	26	0.8	M
52	0	3	0	3	2,450	2,375	0	3	0	x	x	x	34.5	34.5	34.5	0.5	P
53	0	1	0	1	6,232	5,900	1	0	0	1,050	0	1,050	39	39	39	0.2	P
					Depleted Fields—Arranged Chronologically as to Discovery Date												
54	0	0	0	0	1,020	880	0	0	0	250	0	0			Gas only		
55	0	0	0	0	420	395	0	0	0	x	0	0	28	26	27	0.3	P
56	0	0	0	0	875	825	0	0	0	x	x	x	20	18	19	0.6	P
57	0	0	0	0	3,767	x	0	0	0	x	0	0	32	32	32	0.3	P
58	0	0	0	0	2,870	2,820	0	0	0	x	0	0	40	40	40	0.3	P
59	0	0	0	0	2,940	2,885	0	0	0	x	0	0	37	37	37	0.3	P
60	0	0	0	0	3,780	3,765	0	0	0	x	0	0	32	32	32	0.2	P
61	0	0	0	0	1,820	1,535	0	0	0	x	x	x	31.5	31.5	31.5	0.4	P
62	0	0	0	0	1,160	1,000	0	0	0	x	x	x	34.5	33.9	34.2	0.4	P
63	256	3,726	92	4,041			17	3,680	5								

[22] Four wells capable of flowing shut in; no pipe line outlet.
[26] Midway and Taylor horizons produce oil of the same gravity

Proration

There was little restriction of oil production by the Railroad Commission in the Central Texas area during 1935, although proration of gas production was put into effect for the first time. Output of gas wells was restricted to conform with the policy of the Commission throughout the entire state. Pearsall is the only field in the district with potential possibilities that might necessitate the application of proration rules.

Production

Use of acid treatment in "lime" wells proved satisfactory in fields producing from the Edwards formation, but many operators were confronted with large increases in water as a result of such work. Generally speaking, the improvement in oil production was noted in wells with a producing section above the water level. Fields of the "Serpentine plug" type with lime streaks present likewise were helped by acid treatment. In the Dale field, Caldwell County, much work of this nature was undertaken.

Well pumps capable of handling a large amount of fluid are being used in an experimental manner in several fields. Should they prove practical, considerable oil that otherwise would be unrecovered may be

Table 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-Dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Depth of Hole, Ft.
45	1,010	0.5	Serpentine	CreU	P	15–25	*x*	Intn.	8	Edwards limestone	2,300
46	1,010	2.0	Serpentine	CreU	P	15–25	*x*	Intn.	18	Edwards limestone	2,353
47	*x*	*x*	Georgetown limestone	CreL	L	*x*	59	A	0	Edwards limestone	6,507
48	*x*	*x*	Midway and Taylor	Eoc, CreU	SH	*x*	21	F	14	Edwards limestone	2,835
49	*x*	*x*	Woodbine sand	CreU	S	*x*	25	*x*	1	Woodbine sand	5,002
50	*x*	0.4	Serpentine	CreU	P	15–25	*x*	Intn.	3	Taylor marls	850
51	*x*	*x*	Pearsall sand	CreU	S	20	15	A	1	Trinity sand	10,050
52	*x*	1.5	Crevice, Top Austin	CreU	C	*x*	*x*	F	3	Austin chalk	2,450
53	*x*	*x*	Buda limestone	CreL	L	*x*	40*x*	A	1	Edwards limestone	6,512
			Depleted Fields—Arranged Chronologically as to Discovery Date								
54	1,110	1.8	Taylor sand	CreU	Ss	*x*	13	A	7	Woodbine sand	3,057
55	1,120	1.3	Navarro sand and shale	CreU	SH	18	25	F	15	Glenrose limestone	3,550
56	1,040	1.6	Nacatoch sand	CreU	Ss	14–19	13	AF	25	Woodbine sand	3,480
57	*x*	*x*	Unknown	*x*	*x*	*x*	*x*	Crev.	22	Glenrose limestone	6,050
58	*x*	*x*	Woodbine sand	CreU	SH	25	15	F	35	Woodbine sand	3,509
59	*x*	*x*	Woodbine sand	CreU	SH	25	10	F	9	Woodbine sand	3,310
60	*x*	*x*	Taylor sand	CreU	S	*x*	15	F	3	Edwards limestone	4,281
61	*x*	*x*	Serpentine	CreU	P	12	*x*	Intn.	12	Edwards limestone	2,050
62	*x*	*x*	Buda and Georgetown	CreL	L	20	20	AF	8	Glenrose limestone	1,409
63											

TABLE 2.—*Summary of Drilling Operations in Central Texas in 1935*

Important Wildcats Drilled in 1935

	County	Location: Survey	Location: Section	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
1	Frio[1]	M. L. Carranza-Blk. 7	302	6507	Claiborne	Edwards limestone
2	Bexar[1]	John S. Simpson No. 59		730	Midway Wilcox	Edwards limestone
3	Freestone[1]	J. Y. Aquilera		5003, P.B. to 4854	Reklaw	Woodbine sand
4	Frio[1]	B. G. Gilman No. 16		10050	Claiborne	Trinity sand
5	Guadalupe[1]	Jose K. Davis		2444	Wilcox	Austin chalk
6	Frio[1]	Jos. V. Mason No. 322		6512, P.B. to 6086	Claiborne	Edwards limestone
7	Bandera[2]	G. C. and S. F.	506	5365	Comanchean	Schist
8	Bexar[2]	S. M. Dobie No. 79		2132	Austin Chalk	Schist
9	Hill[2]	C. Sullivan		3398	Taylor	Schist
10	Kimble[2]	G.H. and S.A.-Blk. N	682	4090	Comanchean	Pre-Cambrian
11	Kimble[2]	D. and P.R.R.	1	4857	Comanchean	Ellenberger lime

[1] Discovery well.
[2] Important dry holes.

Important Wildcats Drilled in 1935

	Drilled by	Initial Production per Day: Oil, U.S. Bbl.	Initial Production per Day: Gas, Millions Cu. Ft.	Choke or Bean, Fractions of an Inch	Pressure, Lb per Sq. In.: Casing	Pressure, Lb per Sq. In.: Tubing	Remarks
1	Amerada Pet. Corp.		1.25	2-in. tubg.			Produced total of 106 million cu. ft. and then shut in.
2	Umbren et al.	10		2-in. tubg.			
3	Daniels Oil and Royalty Co.		3	¼	Closed in 1800	Work. pres. 1550	
4	Amerada Pet. Corp.	200		2-in. tubg.			Plugged back from Trinity sand to Pearsall sand.
5	Doody Oil Co.	340		2-in. tubg.			Oil well Austin chalk crevice.
6	Amerada Pet. Corp.	562	2	¾-in. tubg.		29/64-in. chk. 525	Perforated casing to make oil well in Buda limestone.
7	Plateau Oil Co.						Failed to drill through schist
8	Mid-Tex. Dev. Co.						Abandoned in schist.
9	Humble Oil and Ref. Co.						Fresh water.
10	Forest Dev. Co.						Aband. dry in pre-Cambrian.
11	H. F. Wilcox						Salt water.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	29	28
Number of oil wells completed during 1935	75	
Number of gas wells completed during 1935	2	
Number of dry holes completed during 1935	63	98

produced at reasonable costs. To date application of these casing pumps has been limited to areas of high fluid levels.

Price increases for crude announced shortly after the close of the year should result in greater activity during 1936. The entire district will receive its share of wildcat operations, and development in some of the older fields may take on new life. Exploration of deeper zones, particularly the Trinity, may also be expected. A test to this horizon has already been commenced in the Mexia field, and many others are being talked of. Failure to find production of consequence in the eastern section of the state in the past few years no doubt will induce many operators to again turn their atte ntion to Central Texas.

Development and Production in the East Texas District

By Wallace Ralston*

(New York Meeting, February, 1936)

The East Texas area includes the northeast 38 counties of the state of Texas. It covers all, and extends beyond, the borders of what is commonly described as the East Texas Basin. It is one of the most important oil and gas-producing areas of the Mid-Continent Province. It includes four important oil fields—Van, East Texas, Cayuga and Long Lake—and the recent extension of Rodessa field into Cass County, Texas, may prove to be of major size. Four commercial gas fields are in this area—Bethany, Waskom, Cayuga and Long Lake. Up to January, 1936, all of the oil has been produced from the Upper Cretaceous formations, and most of that from the basal member, the Woodbine sand. Gas is produced from both the Upper and Lower Cretaceous formations.

Development in Fields

East Texas Field.—This field continued to dominate the drilling and production situation throughout the United States. There were 4036 wells completed in this field during 1935; that is, 365 more wells than were completed during 1934. Drilling activity was due to close spacing of wells and the addition of 10,000 acres to the field. The field is now drilled to a density of one well to 6½ acres, which is certainly more wells than necessary for economic production of the field. The close spacing of wells is due mostly to the type of proration, which is per well allowable based on a potential test, and does not take acreage into consideration, and also to the numerous small acreage tracts such as town lots and excess strips. The field now has 19,519 producing wells.

The allowable production for the field during 1935 was 161,118,659 bbl.; estimated production, including illegal or "hot oil," was 174,200,150. The illegal production of oil gradually decreased throughout the year, until an estimated low was reached of 20,500 bbl. daily during the months of November and December. The price of oil remained at $1.00 per barrel throughout the year.

As stated, about 10,000 acres were added to the field during the year, making a total of 128,000 productive acres. There is a possibility that

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several thousand more acres will be added during the year 1936, as there are areas that may prove productive between extension wells and the field proper. Most of the extensions have been on the east and west sides of the field. These edge wells are now being completed with cable tools and are drilling as small an amount of sand as is possible to make a well.

This field has 17,630 flowing wells, 1690 pumping wells, 181 on gas-lift and 12 miscellaneous. Bottom-hole pressure has dropped from 1231 lb. for Dec. 31, 1934, to 1196 lb. for Dec. 31, 1935; a drop of 35 lb., or about one pound for each 5,000,000 bbl. produced. The number of wells making water increased from 950 in 1934 to 1126 on Dec. 31, 1935.

Some of the above information is not exact, owing to illegal methods of producing and the reluctance of some operators to record all of their drilling and production methods.

The United Gas Co. completed its gas line to the gas area of the East Texas field during the year. Up to this time all of the gas produced from this area has been used for drilling and lease operations. This gas area is in the extreme southern part of the field. The United

TABLE 1.—*Oil and Gas Production in East Texas District during* 1935

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Oil and Gas[a]	Gas	Total	Total Oil Production, Bbl.: To End of 1935	During 1934	During 1935	Daily Average during Nov. 1935
1	Caddo, *Marion*	31	980			980	7,529,920	34,813	32,077	80
2	Bethany, *Panola*	17			21,000	21,000				
3	Waskom, *Harrison*	11			7,500	7,500				
4	Boggy Creek, *Anderson, Cherokee*	8¾	200			200	4,314,574	218,018	208,201	536
5	Van, *Van Zandt*	6½	4,576			4,576	86,766,704	14,674,766	13,965,500	35,761
6	Van (shallow), *Van Zandt*	3	200			200	94,757	33,474	56,283	165
7	East Texas, *Rusk, Gregg, Smith, Upshur and Cherokee*	5⅓	126,000		2,000	128,000	818,478,385*x*	183,357,000*x*	174,200,150*x*	463,450*x*
8	Long Lake, *Anderson and Leon*	2⅙	1,000		9,000	10,000	141,977	41,028	94,974	580
9	Cayuga, *Anderson*	1⅚	3,000		9,000	12,000	1,876,178	582,050	1,294,128	3,636
10	Shell, *Leon*	2			6,000*x*	6,000*x*				
11	Kittrell, *Houston*	1⅓	160			160	410,032	40,392	369,640	1,089
12	Camp Hill, *Anderson*	1	500			500	125,993		125,993	559
13	Rodessa, *Cass*	7 days	1,500*y*		2,000*y*	3,500*y*	11,377		11,377	1,625
14	Rusk, *Cherokee*	1½	[1]*x*	*x*	*x*	*x*	115,123	35,908	79,215	291
15	Total		138,116		56,500	194,616	919,865,020	199,017,449	190,437,538	

[a] Footnotes to column heads and explanation of symbols are given on page 215.
[1] Not enough development to determine extent of field.

Gas Co. ran 485 million cubic feet of gas from this area during the year of 1935.

In the Joiner district, Rusk County, there is a suggestion of a "gas cap" forming, but the extent to which it will spread or whether it will have any economic significance are not yet known.

Van Field.—There were 82 new producers added to the Van field during 1935; 71 in the Woodbine area and 11 in the Nacatoch sand area. This field produced 14,021,783 bbl. of oil during 1935, which is 686,457 bbl. less than in 1934. The Nacatoch sand wells do not seem to be of any great economic importance, as they are all small pumpers.

Long Lake Field.—The most important development of the year in this field, was the completion of the Tidewater-Seaboard No. 1, Shaw and Cern, for an oil well, three miles north of proven production. The intervening area between the field proper and this well has been tested, and the results were rather disappointing from the standpoint of oil production. The field now has six wells producing oil, five producing oil and gas, and three gas wells. The gas wells are producing varying amounts of distillate. During the year, this field produced 94,977 bbl. of oil, and the Lone Star Gas system ran 2631 million cubic feet of gas.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
								During 1935		At End of 1935				
	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	7,683	2*y*					78		2		31			31
2			103,528	6,828	6,044	20	*y*	*y*	*y*	*y*			146	146
3			42,573	1,756	1,817	5	*y*	*y*	*y*	*y*			82	82
4	21,572	25.5	6,756	269	None		39				21			21
5	18,961	73	No free gas				507	62	1	7	499			506
6	281	5					27	11			27			27
7	6,495*x*	24.4			485	*y*	19,539	4,036		46	19,493		20	19,519
8	142	64.4	2,631		2,631	*y*	14	8			6	5	3	14
9	625	44.8	623.5		623.5	*y*	110	59			87	2	21	110
10			[2]				3							
11	2,563	90					14	5	2		13			13
12	252	70					8	8			8			8
13		1,625	*y*	*y*	*y*	*y*	3	3			1		2	3
14	*x*	97					3	2			3			3
15			156,111.5	8,853	11,600.5		20,345	4,194	5	53	20,189	7	274	20,483

[2] Wells shut in as no line serves this field.

This field probably will be more actively developed during the coming year than at any time since its discovery.

Cayuga Field.—The most important discovery of the year for this district was the Tidewater-Seaboard No. A-21 Wills, in the Edmonson Survey, which is located approximately in the center of the field. This well was drilled to a total depth of 9085 ft. being bottomed in Travis Peak section of the Lower Cretaceous. The well made bottom-hole water from 9085. A series of plug-back jobs followed, testing various depths until the well was finally plugged back to 7416 ft. The casing was perforated from 7210 to 7360 ft., in lower Glenrose and completed making 5.3 million cubic feet of gas and 130 bbl. of distillate testing 55.8 gravity. Closed-in casing pressure was 3150 lb. and tubing pressure 3025. The completion of this deep test not only proves lower Glenrose production for the Cayuga field, but gives hope for deeper pays on all the structural highs of the district. This possibility has caused a steady increase of leasing on all the previously condemned structures, both faulted and anticlines. There were 59 wells completed in this field during 1935. This field produced 1,294,128 bbl. of oil and the Lone Star Gas Co. ran

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1935				Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935					Character of Gas, Approx. Average during 1935	
			Number of Wells					Average at End of		Gravity A. P. I. at 60° F.						
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Misc.	Initial	1934	1935	Maximum	Minimum	Weighted Average	Sulfur Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
1	2,366*y*	2,300*y*		31			*x*	*x*	*x*			40*y*	*y*	P		
2	4,700[3]	1,000[3]					*y*	*y*	*y*						1,000	*y*
3	4,650[3]	1,000[3]					*y*	*y*	*y*						1,000	*y*
4	3,666	3,632		21			650					385	0.24	P		
5	3,000	2,500	366	133			1,250	1,160	1,168	36	32	34	0.8	P		
6	1,200	1,130		27			*x*	*x*	*x*	32	30	31	1.16			
7	3,665	3,632	17,656	1,690	181	12	*e*1,600±	*e*1,231	*e*1,196	41.6	38	39	0.25	M	1,550*y*	2.3
8	5,275	5,178	14				2,150	2,150	2,090			43		P	1,090	0.6
9	4,085	3,822	110				*y*	*e*1,745	*y*			29	1.7	A	1,035	0.25
10	5,825	5,695					700	700	*y*			23.8	0.1	P		
11	2,013	1,995		13			*e*1,962		*e*1,560			38	0.36	P		*y*
12	5,110	5,100		8			900		900			43.5	*y*	P	*y*	*y*
13	6,000	5,950	1				*y*					42	*y*	P		
14	5,125	5,120		3												
15			18,147	1,926	181	12										

[3] Figures for top and bottom of producing zones are from the top of the highest pay to bottom of lowest pay; six or more horizons are present in this interval.

623 million cubic feet of gas during the latter part of the year. Total production to Dec. 31, 1935 was 1,876,178 bbl. The estimate of proven acreage is 3000 acres for oil and 9000 acres for gas. The field is now fairly well defined, and no large extensions are expected to be made during the coming year.

Kittrell Field.—This field is now fully developed and has 13 producing wells on 160 acres. Total production to Dec. 31, 1935 was 410,032 barrels.

Camp Hill Field.—This field was discovered in the early part of 1935 by the Gulf Refining Co. Two producing sands are present in the area; the sub-Clarksville sand in the upper Eagle Ford, and a thin stringer of Woodbine sand at the very top of the Woodbine series, but so far no one well is producing from both sands. Both sands thin out toward the high part of the structure, the first, or sub-Clarksville, sand pinching out first. The discovery well tested both sands, finding salt water in the Woodbine stringer. Wells producing from the Woodbine stringer of sand did not encounter a sub-Clarksville sand. There are eight wells producing at the present time; three from the Woodbine and five from the sub-Clarksville, all pumping. Total production to Dec. 31,

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1933	
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1	Tokio	CreU	S	20*x*	15	A	*y*	*y*	*y*
2	Nacatoch, Blossom, 2,300 several sands to 4,700	CreU CreL	SH	*y*	39	A	39*y*	Sub-anhydrite CreL	5,860
3	Nacatoch, Blossom, 2,300	CreU CreL	S, LS	*y*	16	A	16*y*	Glenrose CreL	4,980
4	Woodbine	CreU	S	25	±34	Ds	43	Woodbine	4,648
5	Woodbine	CreU	SH	25	268	Ds?	59	Trinity (CreL)	7,501
6	Nacatoch	CreU	S	*x*	20	AF	10	Trinity (CreL)	7,501
7	Woodbine	CreU	S	25	30	MU	218	Georgetown CreL	3,894
8	Woodbine	CreU	S	±24	62	A	0	Woodbine	5,468
9	Woodbine	CreU	S	±24	75	A	0	Travis Peak CreL	9,085
10	Woodbine	CreU	S	11	30	A	2	Top Georgetown	6,140
11	Reklaw	Eocene	S	*y*	12	Ds	9	Wilcox Eocene	3,870
12	Eagle Ford and Woodbine	CreU	S	±23	5	AF	3	Georgetown CreL	5,970
13	L. Glenrose	CreL	S & L	20	40	F		L. Glenrose CreL	6,002
14	Woodbine	CreU	S	20	5	MU	2	Woodbine	5,302
15							401		

1935 was 125,993 bbl. I have estimated 500 proven acres for these two sands.

Rusk Field.—This field has three producing wells, all making some salt water. No drilling has been done to the north of these wells, but the area has been fully tested to the south, southeast and southwest. It is very doubtful whether the field will be of any great size. Up to Dec. 31, 1935, this field produced 115,123 bbl. of oil.

Other Areas.—The older productive areas in East Texas were extremely quiet, with few wells, and no new horizons added.

In Freestone County, a few miles southwest of the Cayuga field, J. B. Daniels has drilled two dry gas wells. These do not have any pipe line outlet at the present time.

On Dec. 24, 1935, R. W. Norton completed an oil well in the lower Glenrose of the Lower Cretaceous. This is an extension of the Rodessa field of Louisiana. The well made 45 bbl. per hour on ½-in. choke, and the completion of this well will cause an extensive drilling program along the Rodessa trend in Cass and Marion counties, Texas.

Exploratory Drilling

There were 205 dry holes drilled in exploratory work during the year, resulting in several very promising structures being condemned for Woodbine or shallow production. One gas well and three oil wells were found by this drilling, the most important discovery being the Gulf

Table 2.—*Summary of Drilling Operations in East Texas District during* 1935

Important Wildcats Drilled in 1935

	County or Local Division	Location: Section, Survey	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
1	Anderson[1]	M. Rogers sur	P.B. 5059 5969	Weches Mt. Selman	Georgetown CreL
2	Anderson	D. Parker sur	5335	Reklaw? Mt. Selman	Woodbine CreU
3	Anderson[2]	S. Edmonson sur	P.B. 7416 9085	Reworked (River fill)	Travis Peak CreL
4	Freestone	J. Y. Aquellera sur	4831	Carrizo-Reklaw	Woodbine CreU
5	Angelina	B. J. Thompson sur	2053	Cockfield	Queen City?
6	Angelina	Seth Donegan sur	1204	Cockfield	Queen City?
7	Houston[3]	I. & G.N.R.R. Co. sur	7385	Cook Mountain	Woodbine
8	Wood	W. W. Lanier sur	4988	Upper Wilcox Eocene	Woodbine
9	Cass	Priscilla Evans sur	6002	Queen City	Lower Glenrose
10	Anderson	B. Towles sur	4091	Reworked	Woodbine
	Total				

[1] Discovery well in Camp Hill field; started making gas changed to oil well.
[2] Discovery well in Lower Cretaceous.
[3] Proves that Woodbine sand section extends this far south.

Refining Company's No. 1 Royal-Davey well in the Camp Hill field. The two other oil wells are in Angelina County, producing from the middle or lower Mt. Selman formations, and are very small wells, thought to be of small economic importance at this time. The gas well was drilled in the east central part of Freestone and was completed making 20 million cubic feet of dry gas. A dry hole drilled in Houston County, by Housh, Thompson and Zeni Oil Co., is important because it proved the presence of sand in Woodbine series. This is the greatest distance to the south that Woodbine sand has been found in the East Texas district, and opens for prospecting of this horizon, several known structures.

Summary and Outlook for 1936

Owing to the recent discovery of an oil sand of Paluxy age in the Lower Cretaceous, in Titus County, the deep discovery well in the Cayuga field and the extension of the Rodessa field into Cass County, Texas, I think that we will have one of the most important and most active exploratory drilling programs that this district has ever had.

The drilling should slow down in the East Texas field during the year 1936, and the production should hold about the same as for the past year.

Table 2.—(*Continued*)

Important Wildcats Drilled in 1935

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Gulf	Distillate	Est 10 M	3/8	Est. 1960		P.B. to 5059 Sub Clarksville. Eagle Ford.
2	Tidewater-Seaboard	70.36 per day		3/32	y	y	3 miles N. extension Long Lake field.
3	Tidewater-Seaboard	130 distillate	5.3	3/8	Closed 3150	3025	P.B. to L. Glenrose CreL
4	J. B. Daniels		20	open T.	y	y	Dry gas. No outlet.
5	Lee-Tex Oil Co.	11	Trace	y	y	y	Badly cut oil.
6	Pioneer Expl. Co.	3 to 5 pump					3 to 5 barrels per day pumping.
7	Housh-Thompson & Zeni Oil Co.						Dry and abandoned
8	Atlatl Royalty Corp.						Structurally high. Dry and abandoned.
9	R. W. Norton	45 per hour	1	1/2	y	900	West extension Rodessa field.
10	Joe Worsham	569		29/64	600	470	1½ mile N. extension to Cayuga.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	191	41
Number of oil wells completed during 1935	4179	3
Number of gas wells completed during 1935	15	1
Number of dry holes completed during 1935	111	205

Enforcement of proration seems to be enjoying more success than at any time since its enactment.

Acknowledgments

Various sources were used in compiling the data used in this report. Most of the production figures were taken from our company's pipe line reports. The drilling and completions were taken from the East Texas Oil Scouts Association. It is impossible to get accurate statistics from some of the fields, more especially East Texas. I have used an average figure which I think will represent the true figure very closely. Thanks for information and assistance are due to many persons, but especially to Mr. Frank E. Poulsen, Pure Oil Co., for data on the Van field and to Mr. A. M. Lloyd, of Sun Oil Co., Shreveport, La., for data on Rodessa, Caddo, Bethany and Waskom fields.

Oil and Gas Development on the Texas Gulf Coast during 1935

By W. V. Vietti,* Associate Member A.I.M.E.

(New York Meeting, February, 1936)

Operations in the Texas Gulf Coast during the past year have resulted in the discovery of a number of new fields and the extension of a few of the older fields, both by deeper drilling and by lateral development. Twenty-six new oil and gas-producing areas and discovery of oil or gas in three subsequently abandoned wells have been recorded for a total of 29 new fields of varying importance. Producing areas at Conroe, Manvel, Greta, Pierce Junction, Hastings, Dirks, Thompson, Batson, Mykawa, Tomball, Raccoon Bend, Samfordyce and Saxet have been increased.

Primary geologic studies followed by geophysical mapping or straight geophysical prospects have been responsible for the more important discoveries. These methods have further proved themselves an aid to limiting wildcatting to the more prospective areas and as the chief means to discover reserves in the future.

Production for 1935 totaled 69,560,720 bbl. as compared with 60,850,-360 bbl. for 1934. Strict proration has been in force throughout the discovery of more oil than has been produced. The number of producing oil wells has steadily increased to 4851 at the end of 1935, as compared with 3858 at the end of 1934, owing in part to the prolonged life, because of proration. There were 1272 oil and gas wells completed during 1935, as against 835 in 1934.

New Fields

Pertinent data on the new fields discovered during 1935 are included in Tables 1 and 2. Hence, the discussion of these discoveries will be limited.

Bee County.—Three new gas fields were added during the year: Beeville, discovered by G. M. Church in No. 1 Wood on Sept. 21; Foley, discovered by Dirks Bros. in No. 1 Foley on Feb. 8; and Plummer, discovered by Hynes and Fisher in No. 1 T. M. Plummer on Sept. 2. The three new oil fields added are: Hartzendorf, drilled on fee land by Hartzendorf and completed on May 17 as a small pumper; Ray, southwest of Tuleta, and discovered by Jameson and Burns in No. 1 Campbell

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on March 27; and Worth, discovered on April 30 by Worth Oil Co. in its No. 1-A Rutledge.

Turtle Bay.—Stanolind Oil and Gas Co. proved this Chambers County prospect by its A. D. Middleton No. 1 on Dec. 14. The well was completed at a total depth of 6626 ft., producing from Marginulina (Frio) sand at 6594 to 6618 ft. for 30 bbl. per hour on a ¼-in. choke. This appears to be a major discovery, but additional development will be required to prove the value of the prospect.

Anahuac.—Humble Oil and Refining Co. developed Marginulina (Frio) production in its A. D. Middleton No. 1 in Chambers County on March 14, 1935, producing 727 bbl. in 20 hr., from sand at 7028 to 7088 ft. through ¼-in. and 5⁄16-in. chokes. The field had reached major proportions by the end of the year as the result of several extensions. It would now appear that the field will cover around 4500 to 5500 acres, most of which is held by Humble Oil and Refining Co. A high per-acre yield is anticipated from this field because of the relatively thick reservoir sand, which is variously calculated to average between 60 and 100 ft.

South Houston.—Stanolind Oil and Gas Co. proved South Houston in its first well, Harris County No. 1. The well was tested at several points and finally abandoned in the Vicksburg at 5069 ft. Additional development established production in the Basal Miocene sands with the structure defined as a piercement type salt dome.

Edinburg.—Gulf States No. 1 Engleman in Hidalgo County was drilled to 7508 ft., plugged back and worked over to complete as a large gas well with a spray of distillate from broken upper Frio sand at 6685 to 6720 feet.

Mercedes.—Oil production in Hidalgo County from the Frio sands at 7477 to 7493 ft. was established by the completion of Union Sulphur No. 3, American Rio Grande Land and Irrigation Co. Total depth of the hole was 7496 ft. Initial production through ⅛-in. choke was 192 bbl. daily with 800 lb. tubing and 2500 lb. casing pressure.

Hord's Creek.—Brown and Wheeler No. 1, Mrs. J. R. Kaufman, in Goliad County, is the first well to establish commercial production from the Yegua sand along the Pettus trend in Bee and Goliad counties. The initial completion at 4538 ft. tested 150 bbl. daily through ¼-in. choke with tubing and casing pressures of 1550 lb. The well was drilled deeper to 4581 ft. and encountered salt water; it was finally plugged back to 4545 ft. for a recompletion of 7 bbl. of oil and 9 bbl. of salt water, with a casing pressure of 1550 lb. Subsequent drilling confirmed the productivity of the first sand tested. Brown and Wheeler completed their No. 1-C Mrs. J. R. Kaufman at a total depth of 4566 ft. for an initial production of 165 bbl. in 22 hr. on a ⅛-in. choke.

Mauritz.—Shell Petroleum Corporation's No. 1 Coombs in Jackson County was completed Aug. 18 as a good producer in Frio sand at a

TABLE 1.—*Oil and Gas Production in Texas Gulf Coast in 1935*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
1	Spindletop, *Jefferson*	35	430	0	0	430	122,178,790	1,149,663	948,357	2,370
2	Shallow	35	280	0	0	280	50,846,888	138,071	115,000[1]	1,968
3	Deep	10	150	0	0	150	71,331,902	1,011,592	833,357[1]	402
4	Saratoga, *Hardin*	35	538	0	0	538	27,735,991	297,951	317,698	863
5	Sour Lake, *Hardin*	34	946	0	0	946	77,413,710	508,628	611,983	1,596
6	Batson, *Hardin*	33	567	0	0	567	36,959,973	243,003	616,343	772
7	Big Hill, *Matagorda*	32	15	0	0	15	210,906	(Prod. depleted 1907)		
8	Hoskins Mound, *Brazoria*	32	10	0	0	10	31,755	(Prod. depleted 1907)		
9	Humble, *Harris*	31	2,400	0	0	2,400	120,139,714	1,243,074	1,242,994	3,445
10	Shallow	31	2,110	0	0	2,110	108,402,247	716,709	650,000[1]	*y*
11	Deep	7	290	0	0	290	11,737,467	526,365	592,994[1]	*y*
12	North Dayton, *Liberty*	31	55	0	0	55	2,206,997	59,997	56,120	140
13	Shallow	31	25	0	0	25	800,000	0	0	
14	Deep	8	30	0	0	30	1,406,997	59,997	56,120	140
15	Goose Creek, *Harris*	28	910	0	0	910	74,271,833	1,201,256	1,048,987	2,803
16	Markham, *Matagorda*	28	220	0	0	220	5,343,624	405,650	468,566	1,155
17	Orange, *Orange*	23	400	0	0	400	31,761,884	279,686	261,833	646
18	Brenham, *Austin and Washington*	21	55	0	0	55	329,891	11,643	4,896	18
19	Damon Mound, *Brazoria*	21	270	0	0	270	9,016,136	208,623	197,979	467
20	West Columbia, *Brazoria*	21	350	0	0	350	78,675,400	1,035,175	872,560	2,112
21	Barbers Hill, *Chambers*	20	515	0	0	515	50,089,913	6,821,433	6,780,982	18,329
22	Shallow	20	70	0	0	70	1,745,214	0	0	
23	Deep	8	445	0	0	445	48,344,699	6,821,433	6,780,982	18,329
24	Hull, *Liberty*	18	750	0	0	750	79,981,220	3,476,876	2,320,564	6,157
25	Shallow	18	650	0	0	650	76,362,437	1,310,733	1,256,822	3,209
26	Deep	3	100	0	0	100	3,618,783	2,166,143	1,063,742	2,948
27	Blue Ridge, *Fort Bend*	17	325	0	0	325	9,694,075	309,992	335,328	1,061
28	Pierce Junction, *Harris*	15	312	0	0	312	28,287,263	1,193,108	1,177,255	3,466
29	Edna, *Jackson*	15	0	0	125	125				
30	High Island, *Galveston*	14	200	0	0	200	11,046,052	2,782,789	2,521,916	6,717
31	Stratton Ridge, *Brazoria*	14	25	0	0	25	12,214	(Prod. depleted 1933)		
32	Big Creek, *Fort Bend*	14	200	0	0	200	8,590,993	359,683	355,126	1,051
33	Big Hill, *Jefferson*	13	10	0	0	10	13,853	(Prod. depleted 1924)		
34	Hockley, *Harris*	13	10	0	0	10	23,404	2,590	(Prod. depleted 1935)	
35	Mathis, *San Patricio*	12	0	0	100	100				
36	Boling, *Fort Bend, Wharton*	11	200	0	0	200	4,717,841	143,461	183,925	719
37	South Liberty, *Liberty*	11	344	0	0	344	14,822,862	174,984	199,868	609
38	Kingsville, *Kleberg*	10	90	0	175	265	638,693	23,363	22,994	54
39	Nash, *Brazoria. Fort Bend*	10	120	0	0	120	1,637,261	12,660	13,816	25
40	Orchard, *Fort Bend*	10	200	0	0	200	2,890,532	452,395	239,016	600
41	Fannett, *Jefferson*	9	65	0	0	65	1,586,166	193,200	239,534	855
42	Allen, *Brazoria*	9	10	0	0	10	78,333	4,336	3,242	7
43	Clay Creek, *Washington*	8	300	0	0	300	3,251,939	263,830	361,641	1,044

[a] Footnotes to column heads and explanation of symbols are given on page 215.
[1] Estimated.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Producing Oil and Gas[c]	At End of 1935: Producing Gas Only	At End of 1935: Total Producing
1	284,137	15					1,343	0	*y*	77	151			151
2	181,596	*y*					1,002	0	*y*	*y*	*y*			*y*
3	475,546	*y*					341	0	*y*	*y*	*y*			*y*
4	51,554	4					739*x*	0	*y*	*y*	219			219
5	81,833	9					779*x*	4	6	*y*	179			179
6	65,186	4					984*x*	8	*y*	*y*	192			192
7	14,060						3							
8	3,175						6							
9	50,058	14					1,680	16	*y*	*y*	253			253
10	51,375	*y*					1,591	0	*y*	*y*	*y*			*y*
11	40,474	*y*					89	16	*y*	*y*	*y*			*y*
12	40,127	13					62	0	*y*	0	11			11
13	32,000						52	0	*y*	0	0			0
14	46,900	13					10	0	*y*	0	11			11
15	81,617	34					861	1	10	*y*	80			80
16	24,289	43					130	1	1	0	27			27
17	79,405	13					314	1	5	0	49			49
18	5,998	1					62	0	8	0	21			21
19	33,393	16					122	2	*y*	*y*	29			29
20	224,787	96					233	0	*y*	*y*	37			37
21	13,167	102					374	43	28	3	168			168
22	24,932						42	0	0	0	0			0
23	108,640	102					332	43	28	3	168			168
24	106,641	33					713	29	*y*	*y*	185			185
25	117,481	26					614	0	*y*	*y*	123			123
26	36,187	45					99	29*y*	*y*	*y*	62			62
27	29,828	23					167	7	0	*y*	47			47
28	90,664	46					227	19	3	*y*	72			72
29			*y*	*y*	*y*	*y*	11	0	*y*	*y*			*y*	*y*
30	55,230	114					87	22	2	12	50			50
31	488						4							
32	42,995	44					70	4	*y*	*y*	19			19
33	1,385						3							
34	2,340						3		1					
35			*x*	*x*	*x*	*x*	5	0	*y*	*y*			*y*	*y*
36	23,589	9					150	11	*y*	*y*	82			82
37	43,090	12					318	11	2	*y*	51			51
38	7,097	8	*y*	*y*	*y*	*y*	19	1	*y*	*y*	7		*y*	7*y*
39	13,644	25					24	0	0	0	1			1
40	57,810	55					25	2	0	0	12			12
41	24,402	66					14	8	*y*	*y*	14			14
42	7,833	7					5	0	0	0	1			1
43	10,840	25					54	9	*y*	*y*	42			42

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1935					Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935				
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells					Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]
			Flowing	Pumping	Gas-lift	Air-lift	Misc.		1934	1935	Maximum	Minimum	Weighted Average		
1	1,610		10	141				*x*	50	*y*			26	0.24	A
2	1,000		*y*	*y*				*x*					25		A
3	3,400		*y*	*y*				400	50	*y*	29	23	26		A
4	1,000			219				*x*			22	16	20	*x*	A
5	900		13	166				*x*			31	16	20	*x*	A
6	1,250		9	183				*x*	125		29.8	20	27.7	*x*	A
7	862							*x*			*x*	*x*	*x*	*x*	A
8	623	600						*x*			*x*	*x*	*x*	*x*	A
9	1,800		5	248					75		45	17	33	0.108	A
10	1,200[2] 1,700		*y*	*y*				*x*			36	17	27		
11	4,800		*y*	*y*				315			45	38	41		
12	3,800			11							415	22	28	0.12	A
13	1,200							*x*					24		
14	4,800			11				400					36	0.12	A
15	2,800			80				*x*			36	19.2	23	0.19	A
16	1,500		5	22				*x*	325	*y*	27.6	23	23.2	0.21	A
17	4,000		2	47				*x*			27.4	20.4	23.8	0.18	A
18	225			21							19	14	17	*x*	A
19	2,700			29				*x*			33	21	26	0.372	A
20	3,200		3	33		1		*x*	93		32	18	28	*x*	A
21	4,500		50	106	11	1					30	24.8	26	0.214	A
22	2,300														
23	5,200		50	106	11	1		296	309	877	30	24.8	26	0.214	A
24	2,900		8	177							41	17	32.7	0.28	A
25	2,200		1	122				*x*			34	17	24		
26	4,650		7	55				530	85	*y*	41	36	38		
27	3,600		5	42				385	75	*y*	45	20	26	0.25	A
28	4,300		21	51				355	195	*y*	41.5	21	27.6	0.173	A
29	3,400							1,100	*x*	*x*					
30	4,325		21	29				527	362	*y*	39	23	33	*x*	A
31	4,360							*x*					29	*x*	A
32	3,850		3	16				400	400	*y*	42.7	19.5	28	*x*	A
33	2,500							*x*					*x*	*x*	A
34	2,250	2,220						40			37	22	32	*x*	A
35	2,385	2,375						935	*x*	*x*					
36	1,375		38	44				*x*	10	*y*	33.7	21.3	28.3	0.41	A
37	3,500		3	48				50	*y*		47	20.5	24	0.18	A
38	2,350	2,050		7				*x*					21.5	0.14	A
39	4,300			1				800					19.9	*x*	A
40	3,750		4	8				375	218	*y*	41.4	22.1	28.3	*x*	A
41	4,660		3	11				540			37	26	30	*x*	A
42	5,030			1				200			41.3	28.3	34.3	0.105	A
43	1,250		7	35				350	150	*y*	27	23	26	0.36	A

[2] Cap rock.

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1935: B.T.U. per Cu. Ft.	Character of Gas Approx. Average during 1935: Gal. Gasoline per M.C. Ft.	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Porosity[i]	Producing Rock: Net Thickness, Average Ft.	Producing Rock: Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Deepest Zone Tested to End of 1935: Depth of Hole, Ft.
1	x							Ds	125	Vicksburg	6,654
2			Cap rock, Pli	Pre-Ter, Pli	L SH	Cav. Por	x				
3			Mio, Mid Olig, Frio	Mio, Olig	Ss	Por	69				
4			Lagarto, Mid Olig Cap rock	Mio, Pli, Olig, Pre-Ter	Ss, L	Por	x	Ds	216x	Yegua	6,275
5	x	x	Cap rock, Pli Mio, Mid Olig Jackson, Yegua	Pre-Ter, Pli, Mio, Olig, Eoc	L Ss SH	Cav Por	x	Ds	190	Yegua	7,012
6	x	x	Cap rock, Lissie, Lagarto, Mid Olig, Yegua	Pre-Ter, Pli, Mio, Olig, Eoc	L, SH	Cav Por	74x	Ds	81x	Yegua	5,204
7			Cap rock, Mio	Pre-Ter, Mio	L, x	Cav Por	x	Ds	5	x	3,000x
8			y	y	SH	Por	x	Ds	39	Salt	1,150x
9							60x	Ds	803	Cook Mt.	8,181
10			Cap rock, Mio, Olig,	Pre-Ter, Mio, Olig	L, S	Cav, Por	x				
11			Mid Olig, Jackson Cockfield, Yegua	Olig, Eoc	SH	Por	400				
12						Por		Ds	108	Yegua	5,700
13			Pli, Mio	Pli, Mio	Ss	Por	x				
14			Mio, Frio, Vicksburg	Mio, Olig	SH	Por	32x				
15			Pli, Mio, Mid Olig, Frio, Vicksburg	Pli, Mio, Olig	SH Ss	Por	40x	D	261	McElroy	6,855
16			Cap rock, Pli, Mio, Mid Olig	Pre-Ter, Pli, Mio, Olig	L, SH Ss	Cav Por	46x	Ds	137	Vicksburg	6,044
17			Pli, Mio, Mid Olig, Frio	Pli, Mio, Olig	Ss, SH	Por	30x	D	87	Frio	6,158
18			Oakville, Cockfield	Mio, Eoc	SH	Por	10x	Ds	61x	Sparta	3,572
19			Mio, Mid Olig, Vicksburg	Mio, Olig	SH	Por	43x	Ds	175	Vicksburg (y)	7,583
20			Pli, Mio, Mid Olig, Frio, Vicksburg	Pli, Mio, Olig	Ss	Por	250	Ds	168	Vicksburg	6,306
21					Ss	Por	75x	Ds	143	McElroy	8,148
22			Pli, Mio	Pli, Mio	Ss	Por	42x				
23			Mio, Frio	Mio, Olig	Ss	Por	80x				
24						Por		Ds	210	Cook Mt.	6,676
25			Pli, Mio, Mid Olig	Pli, Mio Olig	S	Por	60				
26			Yegua	Eoc	SH	Por	150x				
27			Mio, Mid Olig, Frio	Mio, Olig	SH	Por	60	Ds	106	Vicksburg	6,024
28			Mio, Vicksburg	Mio, Olig	SH	Por	130x	Ds	167	Vicksburg	6,194
29	y	y	Mio, Frio	Mio, Olig	S	Por	30	D	8	Frio	6,425
30			Pli, Mio, Mid Olig	Pli, Mio, Olig	S, SH	Por	35x	Ds	111	Mid. Olig	6,275
31			Mio	Mio	S	Por	10	Ds	108	Mid. Olig	7,624
32			Pli, Mio, Mid Olig, Frio	Pli, Mio, Olig	SH	Por	54	Ds	57	Claiborne	3,867
33			Pli, Mio	Pli, Mio	S	Por	10	Ds	55	Mio	6,010
34			Cap rock, Frio	Pre-Ter, Olig	L, SH	Cav Por	30	Ds	64	Caddell	7,063
35	y	y	Mio	Mio	S	Por	10	ML	6	McElroy	5,526
36			Cap rock, Mid Olig, Frio	Pre-Ter, Olig	L, SH	Cav Por	60	Ds	72	Olig	5,546
37			Mio, Mid Olig, Jackson, Yegua	Mio, Olig, Eoc	SH,Ss	Por	100x	Ds	115	CreU in cap rock Yegua on flank	2,022 5,176
38			Lagarto	Mio	S	Por	20	D	49	Frio	6,922
39			Mio, Mid Olig	Mio, Olig	S, SH	Por	60x	Ds	39	Vicksburg	6,232
40			Mio, Mid Olig	Mio, Olig	SH, S	Por	60	Ds	17	Cook Mt.	7,282
41			Mio, Mid Olig, Frio	Mio, Olig	SH	Por	60x	Ds	33	Vicksburg	6,661
42			Mio	Mio	SH	Por	100	Ds	30	Mio	5,958
43			Claiborne, Wilcox	Eoc	SH	Por	120	Ds	46	Wilcox	5,517

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
44	Raccoon Bend, *Austin*	8	2,445		600	3,045	15,114,795	1,488,627	1,681,210	4,889
45	Shallow	8	1,371			1,371	14,379,183	1,352,185	1,082,040	2,861
46	Deep	2	1,074			1,074	735,612	136,442	599,170	2,028
47	Sugarland, *Fort Bend*	8	1,163	0	0	1,163	23,134,908	2,185,378	2,098,407	5,524
48	Refugio, *Refugio*	8	1,877		2,720	4,597	31,823,470	1,418,849	1,437,200	3,949
49	Shallow		1,025			1,025	20,506,435	679,891	650,000[1]	*y*
50	Deep		852			852	11,317,035	738,959	787,200[1]	*y*
51	Rockland, *Jasper*	8	20	0	0	20	30,067	2,718	797*y*	0
52	Esperson, *Liberty*	7	360	0	0	360	3,553,887	446,445	439,300	1,150
53	Hankamer, *Liberty*	7	400	0	0	400	3,528,945	374,914	553,909	1,401
54	Lost Lake, *Chambers*	7	55	0	0	55	775,506	68,313	85,737	270
55	Port Neches, *Orange*	7	175	0	0	175	3,475,939	567,261	596,196	1,876
56	Agua Dulce, *Nueces*	6	0	500	9,500	10,000	201,808	99,509	72,894	60
57	Shallow		0	0	*y*	*y*				
58	Deep		0	500	*y*	*y*	201,808	99,509	72,894	60
59	Danbury, *Brazoria*	6	50	0	0	50	4,549	3,642	(Prod. depleted 1934)	
60	Mykawa, *Harris*	6	270	0	0	270	1,144,224	150,196	710,024	3,097
61	Moss Bluff, *Chambers, Liberty*	6	10	0	0	10	179,235	(Prod. depleted in 1933)		
	Pettus District:									
62	Pettus, *Bee*	6	600	0	100	700	7,534,651	594,895	499,411	1,314
63	No. Pettus, *Bee, Goliad, Karnes*	6	460	20	20	500	1,284,842	352,180	446,262	1,332
64	Normanna, *Bee*	6	20	0	0	20	45,914	4,595	2,856	0
65	Kimball, *Bee*	6	25	0	0	25	13,559	7,625	4,434	7
66	Tuleta, *Bee*	4	80	25	0	105	144,294	12,675	8,855	26
67	W. Tuleta, *Bee*	2	800	0	0	800	816,227	107,522	708,705	1,606
68	Caesar, *Bee*	2	285	0	175	460	279,582	6,870	272,712	786
69	Dirks, *Bee*	2	700	0	0	700	648,512	5,069	643,443	3,495
70	Foley, *Bee*	1	0	10	0	10	335		335	0
71	Hartzendorf, *Bee*	1	20	0	0	20	1,011		1,011	6
72	Ray, *Bee*	1	400	0	0	400	298,052		298,052	1,595
73	Worth, *Bee*	1	20	0	0	20	9,691		9,691	59
74	Saxet, *Nueces*	6	0	3,300	1,000	4,300	3,319,327	750,189	1,049,000	5,306
75	White Point, *San Patricio*	6	0	20	3,865	3,885	73,040	9,876	11,908	20
76	Slick, *Goliad*	5	25	0	0	25	53,402	1,113	0*y*	
77	Lucas, *Live Oak*	5	0	500	4,000	4,500	146,434	28,630	63,470	144
78	Manvel, *Brazoria*	5	1,518	0	0	1,518	4,355,628	1,034,764	2,485,585	7,712
79	Shallow		748	0	0	748	*y*	*y*	*y*	*y*
80	Deep		993	0	0	993	*y*	*y*	*y*	*y*
81	Thompsons, *Fort Bend*	5	3,185	700	0	3,885	18,203,073	4,202,750	4,094,375	10,640
82	McFaddin, *Victoria*	5	0	10	845	855	65,223	7,253	37,895	40
83	O'Connor, *Refugio, Victoria*	4	0	250	0	250	247,679	111,153	112,846	298
84	Arriola, *Hardin*	4	100	0	0	100	1,073,432	459,113	410,000	1,335
85	Buckeye, *Matagorda*	4	50	0	0	50	523,635	76,852	71,787	230
86	Conroe, *Montgomery*	4	18,000	0	0	18,000	56,951,905	17,272,399	15,575,606	37,812

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Producing Oil and Gas[c]	At End of 1935: Producing Gas Only	At End of 1935: Total Producing
44	11,164	35	2,178	89	516	2.1	184	38	2	20	121			121
45	10,480	30					*y*	*y*	*y*	19	75			75
46	684	45					*y*	*y*	*y*	1	46			46
47	19,820	112					70	1	0	13	48			48
48	16,954	46	*x*	*x*	*x*	*x*	396	16	*y*	*y*	86			86*y*
49	20,006	*y*					271	*y*	*y*	*y*	*y*			*y*
50	13,283	*y*					125	16*y*	*y*	*y*	*y*			*y*
51	1,503						8	0	*y*	*y*	0			0
52	9,872	37					32	3	2	1	32			32
53	8,876	70					33	16	1	0	26			26
54	14,100	34					12	1	0	2	8			8
55	19,862	104					19	4	0	0	18			18
56	404	*y*	23,044	1,180	1,812	*y*	23	2	0	8		*y*	*y*	15
57			8,757	751	553	*y*	*y*	*y*	*y*	*y*			*y*	*y*
58	404	*y*	14,287	429	1,259	*y*	*y*	*y*	*y*	*y*		*y*		*y*
59	91						2							
60	4,238	115					34	25	3	0	27			27
61	17,923						5							
62	12,559	33	*y*	*y*	*y*	*y*	84	0	4	0	38		*y*	38*y*
63	2,570	70	*y*	*y*	*y*	*y*	48	12	2	*y*	36	2	2	40
64	2,296	0					3	0	0	1	0			
65	542	7					3	0	0	0	1			1
66	1,312	9					12	0	0	1	3			3
67	1,020	25					70	44	11	*y*	57			57
68	981	29	*y*	*y*	*y*	*y*	36	27	2	*y*	28		6	34
69	900	57					71	69	0	0	71			71
70	33	0	*y*	*y*	*y*	*y*	1	1	0	1*y*				0
71	50	6					1	1	0	0	1			1
72	745	53					35	35	0	2	33			33
73	485	30					2	2	0	1	1			1
74	1,006	65	*y*	*y*	*y*	*y*	115	52	*y*	*y*	85		30*y*	115*y*
75	3,652	20	*y*	*y*	*y*	*y*	35	0	*y*	*y*	1	0	*y*	1*y*
76	2,136						3	0	*y*	*y*				
77	293	16	*y*	*y*	*y*	*y*	36	4	*y*	6	2	8	14	24
78	2,870	76					101	54	0	0	101			101
79	*y*	*y*					56	9	0	0	56			56
80	*y*	*y*					45	45	0	0	45			45
81	4,670	55					203	25	*y*	*y*	192			192
82	6,522	40	917	227	163	1	4	1	0	0	0	1	1	2
83	990	60	*y*	*y*	*y*	*y*	11	0	2	1	5	0	2	7
84	10,734	121					13	5	0	0	11			11
85	10,473	115					2	0	0	0	2			2
86	3,152	42					902	59	*y*	*y*	890			890

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Flowing	Pumping	Gas-lift	Air-lift	Misc.	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1934	Average at End of 1935	Character of Oil, Approx. Average during 1935, Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
44	1,020[3] 4,100	1,010[3] 3,125	44	77							38	16	30	0.18	A
45	3,150 3,475	3,125 3,450		75				275			32	16	28		
46	4,100	4,000	44	2				e1,760	e1,755	550[4]	38	32	34		
47	3,575		41			7		500[4]	350[4]	350[4]			28	0.31	A
48	2,700[3] 4,900		50	36				1,200	874	*y*	60	21	31	0.14	A
49	3,700	3,600	*y*	*y*				550	*y*	*y*			33	0.10	
50	5,400		*y*	*y*				1,700	*y*	*y*			29	0.169	
51	1,275	1,260											21	0.26	A
52	2,970		3	29				100	275		32	21	24	0.26	A
53	3,975		7	19				424	90	*y*	26	15.7	23.4	0.33	A
54	2,781	2,729		8				490			23.8	18	22.4	0.22	A
55	3,942		4	14				155*x*	1,000*x*	1,700	38	19.4	23	0.26	A
56			*y*										59	0.022	M
57	2,005	1,995						865	800	800					
58	4,820	4,804	*y*					1,900	1,850	1,650			59	0.022	M
59	1,579	1,572											*x*	*x*	A
60	4,593		14	13				290	350	*y*	30.5	27	28.2	0.141	A
61	830[2] 5,800	800						280					29.7	0.21	A
62	3,900	3,860	6*y*	32*y*				236	125	*y*	49	45	47	0.05	M
63	3,664	3,655	34*y*	4*y*				*y*	410	*y*	51	45	47	*x*	M
64	3,630	3,613						150	100				40	*x*	M
65	3,650			1*y*				100	100				45.1	*x*	M
66	4,138	4,102		3*y*				534	150		51	45	46	*x*	M
67	3,960	3,935	52	5				792	784	*y*	51	45	47	*x*	M
68	3,055	3,040	26	2				1,160[3] 315	990 235	*y*			26	*y*	M
69	3,875	3,859	71					1,000	1,000	850			45	*y*	M
70	3,445	3,404						1,050					54.5	*x*	M
71	3,651	3,642		1									45	*x*	M
72	3,944	3,838	33					450		450			46	*y*	M
73	3,407		1*y*					850		*y*			30.3	*x*	M
74	2,360[3] 4,500	2,340 4,480	69	1	15			1,325[3] 745	1,240 646	1,200 600	262	20	24	0.18	M
75	2,375[3] 4,902[6]	4,880	1					764[3] 2,000[6]	477 1,740	*y*			31	0.094	M
76	4,225	4,211						550	465				48.6	0.044	M
77	2,090[3] 3,533 5,287	2,020 3,500 5,200	8	2				874[3] 1,400	340 1,225	375 1,000	50	24	36	0	A
78			69	30	2						28	22.8	25	*y*	A
79	4,016	3,990	25	29	2			1,500	1,300	e1,700			24	*y*	A
80	5,160	5,000	44	1				2,200	2,100	e2,400			26	*y*	A
81	5,300	4,925	187	5				750[4]	560[4]	550[4]			25	0.20	A
82	2,470[3] 6,187	2,440 6,176	 1					1,185[3] 1,725	*x* *x*	1,050 1,220			 46	 0.16	 A
83	3,100	3,075	2		3			365[4]	196[4]	110[4]			35	0.16	A
84	4,300		4	7				440	542	400	42	27	34	0.126	A
85	7,926	7,831		2				1,045					38	0.07	A
86	5,150	5,000	873	17				e2,275	e2,087	550[4]			38	0.05	M

[3] Gas.
[4] Flowing pressure through tubing on small choke.
[6] Oil.

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1935: B.T.U. per Cu. Ft.	Character of Gas Approx. Average during 1935: Gal. Gasoline per M.C. Ft.	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Porosity[i]	Producing Rock: Net Thickness, Average Ft.	Producing Rock: Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Deepest Zone Tested to End of 1935: Depth of Hole, Ft.
44	1,000	0.8			Ss	Por		D	59	Cook Mt.	6,563
45			Whitsett, McElroy	Eoc	Ss	Por	25				
46			Cockfield	Eoc	Ss	Por	33				
47			Heterostegina Marginulina, Frio	Olig	Ss	25	80	Ds	4	Vicksburg	4,471
48	*y*	*y*			SH	Por	30	D	95	McElroy	9,134
49			Mio	Mio	SH	Por	30				
50			Frio	Olig	SH	Por	30				
51			Cockfield	Eoc	Ss	Por	10	MF	11	Cockfield	1,320
52			Mio, Mid Olig, Yegua	Mio, Olig, Eoc	SH	24	36	Ds	19	Crockett	9,375[9]
53			Mio, Frio	Mio, Olig	SH	Por	29	D	12	Vicksburg	7,096
54			Frio	Olig	Ss	Por	33	Ds	17	Frio	7,471[9]
55			Pli, Mio, Frio	Pli, Mio, Olig	SH, S	Por	40	D	7	Vicksburg	7,250[9]
56	1,000	0.6			SH	Por		DF	3	Frio	6,012
57			Fleming	Mio	SH	Por	10				
58		0.6	Frio	Olig	SH	Por	16				
59			Fleming	Mio	SH	Por	7	Ds	13	Olig	7,495
60			Mio, Frio, Heterostegina	Mio, Olig	SH	Por	32	D	13	Whitsett	5,840
61			Cap rock, Marginulina	Pre-Ter, Olig	SH	Cav Por	33	Ds	61	Vicksburg	7,375
62			Cockfield	Eoc	Ss	Por	19	DF	20	Queen City	7,569
63	*x*	*x*	Cockfield	Eoc	Ss	Por	15	DF	5	Yegua	4,552
64			Cockfield	Eoc	SH	Por	17	D	2	Cook Mt.	4,595
65			Cockfield	Eoc	S	Por	7	D	10	Yegua	4,503
66			Cockfield	Eoc	SH	Por	13	DF	5	Weches	6,062
67			Yegua	Eoc	SH	Por	10	DF	11	Yegua (*y*)	4,510
68			Cockfield, Yegua	Eoc	Ss	Por	15	DF	8	Yegua	3,423
69			Cockfield	Eoc	Ss	Por	16	DF	7	Yegua	4,301
70			Hockleyensis	Eoc	SH	Por	10	A(*x*)	1	Yegua (*y*)	4,146
71			Cockfield	Eoc	SH	Por	9*y*	A	1	Cockfield	3,651
72			Cockfield	Eoc	SH	Por	15*x*	DF	3	Cockfield	3,962
73			Cockfield	Eoc	SH	Por	5	D	10	Yegua (*y*)	3,705
74			Oakville, Mid Olig	Mio, Olig	Ss	Por	10[3] 16	D	31	Frio (*x*)	7,060
75			Lagarto, Mid Olig	Olig	Ss	Por	10	D	27	Frio	7,211
76			Cockfield	Eoc	Ss	Por	10	D	4	Yegua	4,574
77			Catahoula[3] Frio, Yegua	Mio Olig, Eoc	S SH	Por	28	D	17	Cook Mt.	6,789
78						Por	24	D	26	Vicksburg	7,957
79			Miocene	Mio	SH	Por	23				
80			Marginulina	Olig	Ss	Por	26				
81			Mid Olig, Frio	Olig	Ss	25	84	D	26	Frio	6,829
82			Catahoula,[3] Frio	Mio Olig	S	Por	20[3] 10	D	9	Vicksburg	7,023
83			Mio, Catahoula	Mio, Olig	SH	Por	20	DF	7	Olig	5,748
84			Frio	Olig	Ss	Por	50*x*	Ds	9	Yegua	6,743
85			Frio	Olig	SH	Por	60	D	4	Frio	9,459
86	1,128	1.0	Upper Cockfield, Conroe	Eoc	Ss	27*x*	14[7] 56[8]	D	43	Cook Mt.	5,993

[7] Upper Cockfield sand.
[8] Conroe sand.
[9] In salt.

total depth of 5650 ft. Dry holes to the southwest, northwest and northeast have dampened any prospects for a major discovery.

Jim Wells County.—O. W. Killam No. 4 Wade in the Sandia gas field is interesting because of its initial completion as a good oiler in the Frio, although the well was later deepened and finally abandoned.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
87	Keeran, *Victoria*	4	100	0	0	100	352,721	101,434	108,890	323
88	Pledger, *Brazoria*	4	0	20	1,100	1,120	17,068	1,100	62	0
89	Garwood, *Colorado*	3	10	0	0	10	2,024	(Prod. depleted 1933)		
90	Greta, *Refugio*	3	3,914	1,000	0	4,914	9,839,160	3,913,756	4,708,780	14,582
91	Livingston, *Polk*	3	1,400	0	0	1,400	2,179,666	730,003	1,037,388	2,940
92	Premont, *Jim Wells*	3	0	200	0	200	7,803	3,840	3,963	0
93	Tomball, *Harris*	3	6,750	0	1,000	7,750	3,132,926	989,590	1,910,336	6,418
94	Ace, *Polk*	2	0	50	0	50	33,650	12,650	21,000*y*	59
95	Angelita, *San Patricio*	2	40	0	0	40	30,500	22,782	7,718	0
96	Brookshire, *Waller*	2	50	0	0	50	10,642	2,640	8,002	16
97	Cleveland, *Liberty*	2	350	0	0	350	414,143	171,340	242,803	847
98	Coleto Creek, *Victoria*	2	0	350	350	700	220,471	16,952	203,519	719
99	Dickinson, *Galveston*	2	0	1,000	0	1,000	296,815	6,903	289,912	1,490
100	Eureka, *Harris*	2	0	50	0	50	5,811	1,360	4,451	0
101	Hastings, *Brazoria*	2	1,500	0	0	1,500	623,815	0	623,815	3,899
102	Kittrell, *Houston*	2	120	0	0	120	417,328	35,327	382,001	1,128
103	Louise, *Wharton*	2	2,204	0	0	2,204	600,581	187,848	412,733	1,094
104	McNeil[10] *Live Oak*	2	100	0	0	100	113,482	13,489	99,993	275
105	Old Ocean, *Brazoria*	2	100	0	0	100	120,938	17,568	103,370	457
106	Port Lavaca, *Calhoun*	2	200	0	30	230	146,336	5,030	141,306	783
107	Samfordyce, *Hidalgo*	2	800	0	0	800	1,403,288	165,794	1,237,494	4,536
108	Sinton, *San Patricio*	2	225	100	0	325	54,130	4,396	49,734	169
109	Splendora, *Montgomery*	2	0	10	0	10	996	676	320	0
110	Tomoconnor, *Refugio*	2	2,000	0	0	2,000	561,532	39,320	522,212	2,405
111	Vanderbilt, *Jackson*	2	20	0	50	70	88,020	65,326	22,694	15
112	Van Vleck, *Matagorda*	2	500	0	0	500	40,886	12,353	28,533	153
113	Anahuac, *Chambers*	1	2,500	0	0	2,500	362,039		362,039	2,378
114	Baldwin, *Nueces*	1	150	0	0	150	77,119		77,119	662
115	Dinero, *Live Oak*	1	0	50	20	70	28,376		28,376	145
116	Driscoll, Clara, *Nueces*	1	200	0	0	200	4,829		4,829	0
117	Edinburg, *Hidalgo*	1	0	100	0	100	500*y*		500*y*	*y*
118	Fort Merrill, *Live Oak*	1	50	0	0	50	10,031		10,031	106
119	Hardin-Kenefick, *Liberty*	1	100	0	0	100	13,349		13,349	90
120	Hord's Creek, *Goliad*	1	100	0	50	150	4,165		4,165	60
121	Mauritz, *Jackson*	1	100	0	0	100	14,045		14,045	187
122	Mercedes, *Hidalgo*	1	50	0	0	50	34,182		34,182	134
123	Pickett Ridge, *Wharton*	1	200	0	0	200	49,056		49,056	299
124	Placedo, *Victoria*	1	500	0	50	550	151,175		151,175	987
125	Plymouth, *San Patricio*	1	2,000	0	0	2,000	658,761		658,761	5,196
126	Saxet Heights, *Nueces*	1	300	0	0	300	9,335		9,335	27
127	South Houston, *Harris*	1	200	0	0	200	80,415		80,415	571
128	Taft, *San Patricio*	1	100	0	0	100	2,000*y*		2,000*y*	0
129	Turtle Bay, *Chambers*	1	100	0	0	100	2,858		2,858	0
130	Total		70,988	8,265	25,875	105,128	932,216,808	61,231,892	69,560,720	206,210

[10] Includes Whittington area.

R. Putnam et al. No. 1 Hawkins established a new gas field, San Diego, on Dec. 2. This was also in the Frio sand.

Liberty County.—The Hardin-Kenefick pool was proven by Frazier et al. at No. 2 Lynnott on July 24 after plugging back and perforating casing at 7663 to 7673 ft., in the Yegua formation, from a total depth of 7852 feet.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Producing Oil and Gas[c]	At End of 1935: Producing Gas Only	At End of 1935: Total Producing
87	3,527	104	*y*	*y*	*y*	*y*	6	1	*y*	0	3			3
88	853		*y*	*y*	*y*	*y*	10	4	0	0	0		10	10
89	202						2							
90	2,002	70	*y*	*y*	*y*	*y*	211	22	*y*	*y*	207	0	3	210
91	1,557	48					79	43	4	1	74			74
92	39	0	*y*	*y*	*y*	*y*	4	1	1	1				1
93	464	35	*y*	*y*	*y*	*y*	231	101	*y*	*y*	190		*y*	190*y*
94	673	59	*y*	*y*	*y*	*y*	2	0	0	0	0	1		1
95	762	0					2	0	0	1	0			0
96	213	16					1	0	0	0	1			1
97	1,132	121					11	6	0	0	7			7
98	630	38	*y*	*y*	*y*	*y*	21	10	0	*y*	19		*y*	19*y*
99	297	87.7					19	17	0	1	14	4		18
100	116	0	*y*	*y*	*y*		1	0	0	0		1		1
101	416	97					46	46	0	0	46			46
102	3,480	85					14	10	1	1	12			12
103	272	58					22	14	0	1	20			20
104	1,134	31					9	8	0	0	9			9
105	1,209	229					2	1	0	0	2			2
106	731	65					13	12	0	0	9		*y*	9*y*
107	1,754	40					123*y*	107	*y*	*y*	122			123
108	241	34	*y*	*y*	*y*	*y*	7	6	*y*	2	4		*y*	4*y*
109	100	0	*y*	*y*	*y*	*y*	1	0	0	1				0
110	281	97					27	23	0	0	27			27
111	4,401	15					2	0	0	0	1		*y*	1*y*
112	81	51					4	2	0	0	4			4
113	503	88	100	0	100	2.6	36	36	0	0	36			36
114	575	92					7	7	0	0	7			7
115	568	48					4	4	0	0	0	3	1	4
116	24	0					1	1	0	0	1			1
117			*y*		*y*	*y*	1	1	0	0	0	1		1
118	201						2	2	0	0	2			2
119	133	90					1	1	0	0	1			1
120	42	60					3	2	0	0	2		*y*	2*y*
121	140	187					1	1	0	0	1			1
122	684	45					3	3	0	0	3			3
123	245	150					4	4	0	0	4			4
124	302	62					21	21	0	0	20		*y*	20*y*
125	329	133					44	44	0	0	44			44
126	31	27					4	4	0	0	4			4
127	503	25*x*					9	9	0	0	9			9
128	20	0					1	1	0	0	1			1
129	28	0					1	1	0	0	1			1
130			*y*	*y*	*y*	*y*	13,213	1,272	*y*	*y*	4,830	21*y*	*y*	*y*

Live Oak County.—Dinero, Ft. Merrill and Whittington seem to be unimportant discoveries at this time.

Baldwin.—Magnolia Petroleum Company's No. 1 Baldwin in Nueces County was completed July 11 for 384 bbl. per day through ¼-in. choke

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Flowing	Pumping	Gas lift	Air-lift	Misc.	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1934	Average at End of 1935	Character of Oil, Approx. Average during 1935, Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
87	5,574	5,564	2	1				2,400[3] 1,450	2,200[3] 1,450	*y*	48	28	37	*x*	A
88	6,800	6,600						2,450	2,450	2,450			55.8	*x*	M
89	5,132							1,225					44	*x*	M
90	4,398	4,350	196	6*y*			5[5]	1,350*x*	1,200*x*	900*x*	39	23	24	0.20	A
91	4,276	4,241	65	9				700	561	*x*			40.7	0.053	M
92	3,265	3,248						*x*	1,100	*y*			22.8	*x*	A
93	5,555[3] 5,575	5,375 5,555	185	5				e2,490	e2,417	2,050	45.4	37.5	41	0.041	M
94	4,846	4,828	1					1,400	1,250	*y*			64.9	*x*	M
95	5,380	5,370						1,140	450				33.7	0.132	A
96	2,974	2,955	1					100	100	*y*			24	*x*	A
97	5,840	5,832	7					1,350	1,000	1,000			40	*x*	M
98	2,226[3] 2,835		18	1				*y*	*y*	500*y*	32.5	20	25	*x*	A
99	8,000[3] 8,060 9,140	7,783 8,010 9,080	18					1,250[4]	1,250[4]	1,250[4]	54	37.6	*y*	0.067	M
100	7,695	7,662	1					2,950	2,850	2,850			54.6	*x*	M
101	6,100	6,000	46					2,175		2,175	32	30	31	*x*	M
102	2,055	1,975		12				360	225				24	0.19	A
103	5,157 6,450	5,131 6,445	18	2				1,000	980	660	64.4	20.2	30.5	*x*	A
104	4,434 4,992		9					1,150	1,150	1,400			44.3	*y*	A(*y*
105	8,654	8,632	2					1,650	1,600	*y*			67	*x*	M
106	6,251		8	1				500	500	1,200	61	41	43	*x*	M
107	2,790	2,770	122					1,000	1,000	900			21.5	*y*	*y*
108	5,530	5,520	3	1				2,200	2,100	*y*	49	36.5	47	*x*	A
109	5,841	5,816						2,000					65	*x*	M
110	5,848	5,835	27					667[4]	392[4]	350[4]			36	0.015	A
111	5,582	5,562		1				500	200				32	0.128	A
112	7,075	7,020	4					1,700	1,235	*y*	56	40	48	*x*	M
113	7,080	7,020	36					1,125		1,125	35.1	34.7	34.9	0	M
114	3,877 4,069		4	3				225		225			25.8	*x*	M
115	5,220	5,200	3					1,600		1,350			44.2	*y*	A
116	3,816	3,807	1					750		750			23.8	*x*	M
117	6,770	6,685	1					*y*		*y*			*y*[11]	*x*	*y*
118	4,677	4,668	2					1,100		1,100			46	*y*	A(*y*)
119	7,690	7,665	1					900		900			36.3	*y*	A(*y*)
120	4,584		2					1,550		1,500			47.6	*x*	A(*y*)
121	5,650	5,634	1					650		650			31.8	0.1	A(*x*)
122	7,524	*y*	3					2,500		2,500			56.9	*y*	*y*
123	4,710	4,690	4					900		900			25.2	*x*	A
124	4,773 5,995		18	2				825[12] 1,900[13]		825 1,900			22.8[12] 36.4[13]	*x*	A
125	5,634		44					420		420	38	32	34.2	*x*	A
126	4,096		4					1,650		1,650			23.3	*y*	M
127	4,000	3,900	9					1,600		1,600	29	18	24	*y*	A
128	4,906	4,879	1					600		600			22.8	*y*	*y*
129	6,626	6,594	1					1,150		1,150			32	*x*	M
130			2,678*y*	2,128*y*	31*y*	9*y*	5*y*								

[5] Jetting.
[11] Distillate.
[12] Heterostegina sand.
[13] Frio sand.

from Basal Miocene sands at 3871 to 3879 ft. Subsequent development proved shallower production in the Oakville (upper Miocene) sand at 3223 to 3286 ft. and deeper production in the Basal Miocene at 4060 to 4066 ft.

Saxet Heights.—J. H. Culton No. 1 Baldwin in Nueces County established production in the Basal Miocene at 4077 to 4082 ft. to open

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1935: B.T.U. per Cu. Ft.	Character of Gas Approx. Average during 1935: Gal. Gasoline per M.C. Ft.	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Porosity[i]	Producing Rock: Net Thickness, Average Ft.	Producing Rock: Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Deepest Zone Tested to End of 1935: Depth of Hole, Ft.
87			Frio	Olig	S	Por	10	D	6	Vicksburg	7,715
88			Frio	Olig	S	Por	100	D	6	Frio	8,115
89			Yegua	Eoc	S	Por	12	D	10	Cook Mt.	6,766
90			Catahoula, Heterostegina, Frio	Mio Olig	Ss	Por	20 26x	A	14	Frio	6,725
91			Cockfield	Eoc	SH	25x	10	DF	30	Yegua	5,596
92			Olig	Olig	S	Por	10	D	4	Hockleyensis	6,754
93			Cockfield, Yegua	Eoc	Ss	25x	9	Df	22	Cook Mt.	7,438
94			Cockfield	Eoc	S	25x	9	D	8	Yegua	5,533
95			Frio	Olig	Ss	Por	14	D	2	Frio	6,003
96			Frio	Olig	Ss	Por	16	D	15	Hockleyensis	7,215
97			Cockfield	Eoc	Ss	Por	8	D	5	Cook Mt.	8,735
98			Catahoula, Frio	Mio, Olig	S	Por	10	D	11	Frio	5,368
99			Frio	Olig	S	Por	20	DF	3	Frio	9,360
100			Frio (x)	Olig	SH	Por	21	D	3	Frio	8,070
101			Frio	Olig	Ss	Por	45	D	1	Vicksburg (x)	8,792
102			Reklaw	Eoc	Ss	Por	20	DF	14	Wilcox	3,870
103			Frio	Olig	S	Por	14	D	7	Vicksburg	8,271
104			Hockleyensis, Cockfield	Eoc	S	Por	10	D	4	Cook Mt.	6,210
105			Frio	Olig	S	Por	22	D	6	Frio	8,657
106			Marginulina	Olig	S	Por	15	DF	6	Frio	6,780
107			Frio	Olig	S	Por	20	A	23	Vicksburg	4,136
108			Frio	Olig	Ss	Por	10	D	1	Frio	7,245
109			Cockfield	Eoc	Ss	Por	9	D	9	Yegua	6,275
110			Frio	Olig	Ss	Por	13	D	0	Frio	7,033
111			Frio	Olig	SH	Por	8	DF	3	Frio	6,619
112			Marginulina, Frio	Olig	SH	Por	21	D	2	Frio	8,708
113			Frio	Olig	SH	Por	80	Df	4	Olig	8,749
114			Mio	Mio	S	Por	12	AF	4	Frio	6,610
115			Yegua	Eoc	S	Por	7y	D	3	Yegua	5,913
116			Mio	Mio	S	Por	10x	DF	0	Mio	3,816
117			Frio	Olig	SH	Por	20y	D	0	Frio	7,508
118			Yegua	Eoc	S	Por	9	D	0	Crockett	5,425
119			Yegua	Eoc	S	Por	20	D	1	Yegua	7,852
120			Yegua	Eoc	SH	Por	10	D(y)	6	Cook Mt. (y)	6,004
121			Frio	Olig	Ss	Por	16	D	4	Vicksburg	7,408
122			Frio	Olig	SH	Por	10	D	2	Frio (y)	8,044
123			Marginulina	Olig	S	Por	16	A	3	Vicksburg	6,546
124			Heterostegina, Frio	Olig	SH	Por	12	Af	5	Frio	6,393
125			Frio	Olig	Ss	Por	10x	DF	8	Frio	6,133
126			Marine Mio	Mio	S	Por	10x	DF	0	Mio	4,098
127			Mio, Frio	Mio-Olig	SH	Por	20x	Ds	4	Olig	6,429
128			Heterostegina	Olig	S	Por	20	D	0	Heterostegina	4,906
129			Marginulina	Olig	S	Por	24	D	0	Marginulina	6,626
130									4,751		

up another field of probable importance. Development probably will be rapid, because all the acreage is divided into small tracts and held by miscellaneous independent operators.

Driscoll, Clara.—Santa Clara No. 1 Clara Driscoll in Nueces County was completed Nov. 20 in the Miocene sand for what seems to be a moderately important discovery.

Plymouth.—Plymouth Oil Company's No. 1-C Welder, in San Patricio County, was completed April 19 in Frio sands at 5501 to 5508 ft. for 295 bbl. daily through ⅜-in. choke. The discovery well was followed by a rapid development of the area and establishment of production in the Frio at 5659 to 5663 ft. and at 5907 to 5911 ft. in two additional discovery wells. Present indications are that this is a comparatively prolific field.

Taft.—Geo. E. Smith No. 1 Britton, in Nueces County, encountered Marginulina (Frio) sand at 4879 to 4906 ft. and tested 201 bbl. in 12 hr.

TABLE 2.—*Summary of Drilling Operations in Texas Gulf Coast in* 1935

Important Wildcats Drilled in 1935

	County	Location Section, Survey	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
1	Bee	John Ryan Sur. A-63	5831	Lissie	U. Cockfield
2	Bee	M. Keeler, A-543	3445	Lissie	Hockleyensis
3	Bee	G. A. Kerr, A-209	3648	Lissie	U. Cockfield
4	Bee	F. L. Chessmon, A-144	2988	Lissie	U. Cockfield
5	Bee	Brooks & Burleson, A-129	3960	Lagarto	U. Cockfield
6	Bee	A. Hadley, A-201	3395	Lissie	U. Cockfield
7	Brazoria	H.T. & B.R.R., Sec. 23	5630	Beaumont	Marginulina
8	Calhoun	M. Sanchez, Tr. 22	6238	Beaumont	Frio
9	Chambers	S. Burney A-7	6626	Beaumont	Marginulina
10	Chambers	H. & T.C.R.R., Sec. 58	7088	Beaumont	Frio
11	Harris	H.T. & B.R.R., Sec. 5	6050	Beaumont	Frio
12	Hidalgo	Mestenas Grant	6720	Beaumont	Frio
13	Hidalgo	Sec. 86, Lot 2082	7496	Beaumont	Frio
14	Goliad	Pedro Trevino	4538	Lissie	Yegua
15	Goliad	M. J. Rios, Sec. 13	5961	Lissie	Cockfield
16	Jackson	Morris & Cummings, Sec. 33	5650	Beaumont	Frio
17	Jim Wells	Casa Blanca, Bode S/D	4850	Lissie	Frio
18	Jim Wells	San Diego Grant	2975	Lissie	Frio
19	Liberty	J. Robison	7852	Beaumont	Yegua
20	Live Oak	Jane Curry, A-43	5208	Lissie	Yegua
21	Live Oak	P. Salinas, A-11	5425	Lissie	Yegua
22	Live Oak	M. M. Shipp, A-788	5028	Lissie	U. Cockfield
23	Montgomery	J. Lindley	3773	Lissie	Cockfield
24	Nueces	J. R. Ward, Sec. 316	4888	Beaumont	Heterostegina
25	Nueces	J. S. McGregor, A-788	3879	Beaumont	B. Miocene
26	Nueces	Wm. Gamble, Sur. A-6	3816	Beaumont	Miocene
27	Nueces	McBride S/D	4082	Beaumont	B. Miocene
28	Refugio	Hardwick, A-159	6263	Beaumont	B. Frio
29	San Patricio	Thomas Amorro	5508	Beaumont	Frio
30	San Patricio	Taft Farm Lands, Addn. 2, Sec. 6	4906	Beaumont	Heterostegina
31	Victoria	Wm. Rupley, A-480	6019	Beaumont	Frio
32	Victoria	Wm. Rupley, A-290	4756	Beaumont	Heterostegina
33	Victoria	Ed. McDonough League	5629	Beaumont	Frio
34	Waller	J. M. Bennett, A-100	7647	Beaumont	Yegua
35	Wharton	I. & G.N., Sec. 39, A-405	4710	Lissie	Marginulina

through ¼-in. and ⅛-in. chokes. The sand thickness and producing characteristics indicate a good per-acre reserve.

Placedo.—Gillespie and Superior Oil Company's No. 1 Henderson Pickering in Victoria County obtained production from the Frio sand at 6005 to 6019 ft. Initial production was 480 bbl. through 3/16-in. choke. The offset wells were completed in the Heterostegina (Frio) sands at 4879 to 4901 ft. and 4727 to 4754 ft., thus establishing two producing Frio horizons.

Pickett Ridge.—The Texas Company's No. 2-A Pierce Estate in Wharton County was completed on June 23 in the Frio sand, at 4693 to

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1935

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	G. M. Church	61	*y*	¼	2100	1600	Dis. Beeville.
2	Dirks Bros.	25	20	*x*	1050	950	Dis. Foley.
3	Hartzendorf	15		Pump			Dis. Hartzendorf.
4	Hynes & Fisher	0	1	⅝	1200	800	Dis. Plummer.
5	Jameson & Burns	192		3/16	100	460	Dis. Ray.
6	Worth Oil Co.	48		½	850	750	Dis. Worth.
7	Bowles & Borsodi	432	*x*	¼	800	700	Ext. Manvel.
8	Steinberger Pet. Co.	680	*x*	¼	1350	950	Ext. Port Lacaca.
9	Stanolind O. & G. Co.	720	*y*	*y*	1150	1100	Dis. Turtle Bay.
10	Humble O. & R. Co.	727	*y*	¼, 5/16	2350	1875	Dis. Anahuac.
11	Stanolind O. & G. Co.	150	*y*	3/16	475	100	Dis. South Houston.
12	Gulf States Dev. Co.	*y*	22	*y*	*y*	*y*	Dis. Edinburg.
13	Union Sulphur Co.	192		⅛	2500	800	Dis. Mercedes.
14	Brown & Wheeler	150		¼	1550	1550	Dis. Hord's Creek.
15	Keystone Royalty		D.S.T.			1350	Junked abandoned.
16	Shell Pet. Corp.	639	*y*	¼	900	650	Dis. Mauritz.
17	Killams	540	*x*	⅜	1150	250	Oil Dis. Sandia, P. & A.
18	R. Putnam	0	3	½	1300	400	Dis. San Diego.
19	Frazier et al	540	*x*	¼	900	775	Dis. Hardin-Kenefick.
20	Smith & Storey	264	*x*	¼	1350	700	Dis. Dinero.
21	Mills-Bennett	180	*x*	¼	100	660	Dis. Fort Merrill.
22	Whittington	37	*x*	1/32	370	270	Dis. Whittington.
23	Gholson et al.	120	*x*	*x*	165	125	Discovery, P. & A.
24	Texon Royalty Co.	192	*x*	¼	500	100	Ext. Saxet.
25	Magnolia Pet. Co.	384	*x*	¼	225	0	Dis. Baldwin.
26	Santa Clara O. Co.	152	*x*	3/32	750	480	Dis. Clara Driscoll.
27	Culton	50	*x*	5/32	1650	1350	Dis. Saxet Heights.
28	Hewitt & Daugherty	346	*x*	3/16	*y*	975	Ext. Greta.
29	Plymouth O. Co.	295	*x*	⅜	420	165	Dis. Plymouth.
30	Geo. E. Smith	402	*x*	¼, ⅛	600	400	Dis. Taft.
31	Gillespie et al.	480	*x*	3/16	1900	1300	Dis. Placedo.
32	Gillespie et al.	201	*x*	¼	825	255	Ext. Placedo.
33	The Texas Co.	0	3	¼	1850	1840	Dis. Warden.
34	Stanolind O. & G. Co.	125	3	¼	2500	2475	Dis. Manor (Katy).
35	The Texas Co.	389	1	¼	900	700	Dis. Pickett Ridge.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	142	63
Number of oil wells completed during 1935	1192	22
Number of gas wells completed during 1935	51	7
Number of dry holes completed during 1935	200	315

4710 ft., through perforated casing from 4705 to 4710 ft. A show of oil in the same sand in well No. 1-A to the south proved productive further north.

Extensions

Manvel dome in Brazoria County has been extended to the north for Oligocene and to the south for Miocene production, both extensions being found on the upthrow side of newly determined faults in this much faulted field.

Pierce Junction reserves have been increased by development of Vicksburg production on the outer edge of the dome.

Other extensions, such as those at Dirks, Conroe and Mykawa, have been due to normal development of the known producing horizons.

Acknowledgment

Information on various fields from the following persons is gratefully acknowledged: L. P. Teas, Humble Oil and Refining Co.; C. A. Warner, Houston Oil Co.; W. H. Spears, United Production Co.; Paul Weaver, Gulf Production Co.; Ira Needham, Jr., Pure Oil Co.; P. L. Vaudoit, Shell Petroleum Corporation; R. A. Weingartner, Stanolind Oil and Gas Co.; W. C. Thompson, General Crude Oil Purchasing Co. The writer is also indebted to John C. Miller, of The Texas Company, for valuable assistance, and to J. A. Barnett, of the same company, for the compilation of statistical data and assistance in the preparation of this report.

Oil and Gas Development and Production in North Texas for the Year 1935

By H. B. Fuqua* and B. E. Thompson*

(New York Meeting, February, 1936)

For a very brief description of the North Texas area, and the general geological features with which it is associated, the reader is referred to the opening paragraph of last year's summary[1]. A more complete discussion of the structure of the area, together with other interesting data concerning it, has been published recently by the Bureau of Economic Geology at the University of Texas[2].

It has been impossible for the authors to isolate the statistics for production for each of the many small pools of this district, as such statistics are not kept by operators except by counties or arbitrary divisions of counties. The total number of wells drilled in Archer, Wichita and Clay counties also has been subject to some estimate, as many of the shallower holes are not reported.

While both routine development in proven or semiproven areas and exploratory drilling during 1935 showed an increase over the year 1934, the discovery of new producing areas of importance did not show improvement over that period. Several extremely local productive spots within semiproven areas were found in Archer, Cooke and Wilbarger counties; and extensions to older producing areas were developed in Archer, Baylor, Cooke, Montague, Wichita and Wilbarger counties.

In Archer County, the Grace and Woods No. 1 Archer County (Fee), 4 miles northwest of Archer City, in the Thomas Glass survey, encountered a sand from 2836 to 2845 ft. of Pennsylvanian (lower Canyon) age, which showed an initial yield of 75 bbl. daily. While its production is of negligible importance, it is given special mention in this review because of the fact that it is producing from a new and deeper horizon than has been previously exploited in the county.

Little deep development occurred in the district during the year. The Walter Gant No. 2 C. M. Worsham in J. M. Swisher survey, about 14 miles east of Henrietta, in Clay County, was abandoned at 5127 ft. in

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* Gulf Production Company, Fort Worth, Texas.

[1] H. B. Fuqua and B. E. Thompson: Oil and Gas Development in North Texas for the Year 1934. *Trans.* A.I.M.E. (1935) **114**, 417.

[2] E. H. Sellards and others: The Geology of Texas. Bur. Econ. Geol., Univ. of Texas, *Bull.* 3401 (1935).

beds of Lower Pennsylvanian (Bend) age. During the latter part of the year interest was shown in northeastern Cooke County and adjacent areas to the north and east, no doubt stimulated by the development of Ordovician production in the Fox field of Carter County, Oklahoma.

TABLE 1.—*Oil and Gas Production in North Texas during* 1935

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres: Oil	Area Proved, Acres: Oil and Gas[a]	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1935	Total Oil Production, Bbl.: During 1934	Total Oil Production, Bbl.: During 1935	Total Oil Production, Bbl.: Daily Average during Nov. 1935
1	Petrolia,[1,2] *Clay*	33	800	1,000	4,000	5,800	6,320,935	198,058	185,881	492
2	Worsham, *Clay*	12	100	0	0	100	206,000	0	abandoned	
3	All fields, *Wichita*	24	40,200	0	0	40,200	249,256,909	5,558,987	5,565,922	14,971
4	All fields, *Wilbarger*	23	9,160	0	0	9,160	55,969,379	3,050,062	2,977,317	7,916
5	All fields, *Archer*	23	21,900	0	0	21,900	98,861,997	7,013,408	6,575,589	15,756
6	All fields, *Montague*	13	3,400	0	0	3,400	22,172,149	1,619,256	2,027,893	5,406
7	Portwood, *Baylor*	11	600	0	0	600	1,751,760	109,499	606,261	4,578
8	All fields, *Cooke*	10	2,600	0	0	2,600	9,175,212	578,143	762,069	2,614
9	Thalia, *Foard*	9	0	100	0	100	223,996	25,036	23,301	69
10	Johnson, *Foard*	3	0	320	400	720	612,996	308,606	248,049	514
11	*Hardeman*[3]									
12	*Knox*[4]									
13	Total		78,760	1,420	4,400	84,580	444,551,333	18,461,055	18,972,282	

Line Number	Average Oil Production, Bbl.: Per Acre to End of 1935[b]	Average Oil Production, Bbl.: Per Well Daily during Nov. 1935	Number of Oil and/or Gas Wells: Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Producing Oil and Gas[c]	At End of 1935: Producing Gas Only	At End of 1935: Total Producing	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Flowing	Oil Production Methods at End of 1935, Number of Wells: Pumping
1	3,570	1	609	13	8	35	419	y	50±	504	1,500	0	419
2			4	0	0	0	0	0	0	0	3,500	0	0
3	6,195	2	10,869	168	458	175	6,604	y	x	6,779	1,500	0	6,604
4	6,100	6	1,842	37	66	27	1,290	y	x	1,317	1,700	0	1,290
5	4,480	4	6,187	464	306	116	3,995	y	0	4,111	1,100	0	3,995
6	6,530	8	816	67	45	25	732	y	21	778	1,000	0	732
7	2,920	33	158	99	3	1	138	y	0	139	1,400	0	138
8	3,530	7	459	120	22	18	375	y	7	400	1,200	0	375
9	2,240	11	12	0	1	0	6	y	4	10	2,000	0	6
10	1,930	103	6	1	0	1	0	5	0	6	3,800	5	0
11													
12													
13			20,962	969	909	398	13,559		82±	14,044		5	13,559

[a] Footnotes to column heads and explanation of symbols are given on page 215.
[1] For Petrolia field, total gas production was, to end of 1935: 98,206, 466 M. cu. ft.; during 1934, 306,357 M. cu ft.; during 1935, 266,565 M. cu. ft. Gas production data not available for other areas.
[2] Includes a few isolated producers and shallow wells with negligible production in other parts of county.
[3] Number of dry holes drilled in county as follows: to end of 1935, 30; during 1935, 5.
[4] Number of dry holes drilled in county as follows: to end of 1935, 14; during 1935, 1.

Several contracts have been signed by reputable parties, assuring some testing of this area in the near future.

Outlook for 1936

In 1935 the production for the district increased about one-half million barrels over 1934, or by approximately the amount of the increase in Baylor County. Losses in some of the older fields were balanced by gains in others. Routine drilling may be expected to continue at about its present rate and current production should be maintained provided further proration restriction is not placed on the fields.

Table 1.—(*Continued*)

Line Number	Character of Oil Approx. Average during 1935					Producing Rock					Deepest Zone Tested to End of 1935	
	Gravity A.P.I. at 60° F.			Sulfur Per Cent	Base[f]	Name	Age[g]	Character[h]	Net Thickness, Average Ft.	Structure[i]	Name	Depth of Hole, Ft.
	Maximum	Minimum	Weighted Average									
1	y	y	36.0	0.15	P	Numerous	Per, Pen	S	10±	A	Cam-Ord	4,289
2						Worsham pay	Pen	L, S	40±	D	Pen (Bend)	5,127
3	41.8	36.1	39.0	0.30	P	Numerous	Per, Pen	S, L	20±	A, M	Pre-Cam	3,502
4	38.5	35.5	37.0	0.65	P	Numerous	Per, Pen	S, L	20±	A, D	Pre-Cam	3,007
5	40.2	36.8	38.5	0.38	P	Numerous	Pen	S, L	10±	M, L	Cam-Ord	5,750
6	34.0	24.1	29.0	0.90	P	Numerous	Pen	S, L	20±	A, D	Pre-Cam	2,915
7	37.0	37.0	37.0	0.38	P	Swastika sand	Pen	S	10±	M, L	Pen (Strawn)	4,265
8	41.0	23.5	35.0	0.65	P	Several	Pen, Ord	S, L	10±	A, D	Pre-Cam	3,790
9	y	y	39.0	0.20	P	Thalia sand	Pen	S, L	22±	D	Pre-Cam	2,550
10	45.0	40.8	43.0	0.30	P	Johnson lime	Pen	L, S	30±	D	Pre-Cam	5,003
11												
12												
13												

Table 2.—*Summary of Drilling Operations in North Texas during 1935*

Important Wildcats Drilled in 1935

	County	Location			Total Depth, Ft.	Surface Formation
		Section	Survey Abstract			
1	Archer	116	J. W. Harris		1253	Permian
2	Archer		Thos. Glass		2845	Permian
3	Clay	38	H. & T.C.R.R.	Blk 4	5127	Permian
4	Cooke		J. Lawson	588	1615	Cretaceous
5	Cooke		BB & C	148	717	Cretaceous
6	Cooke		I. S. Fields	388	1485	Cretaceous
7	Cooke		S. H. Billingsley	1610	1103	Cretaceous
8	Montague		Ed O'Connor		2018	Permian
9	Wilbarger	99	H. & T.C.R.R.	Blk 14	1441	Permian

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1935

	Deepest Horizon Tested	Drilled by	Initial Production per Day	Choke or Bean	Remarks
			Oil, U.S. Bbl.		
1	Pen	L. T. Burns	42	Pump	New pool
2	Pen	Grace & Woods	75	Pump	New pool
3	Pen (Bend)	Walter Gant			Dry hole
4	Pen	J. N. Martin	40	Pump	New pool
5	Pen	W. F. Russell	108	Pump	New pool
6	Pen	Bridwell Oil Co.	150	Pump	New pool
7	Pen	Seitz, Gomegys & Seitz	324	Pump	New pool
8	Pen	Cont'l Oil & Seitz et al.	200	Pump	Old pool, new pay
9	Pen	Lawson & Leawell	375	Pump	New pool

	In Proven Fields and Wildcats
Number of wells drilling Dec. 31, 1935	109
Number of oil wells completed during 1935	967
Number of gas wells completed during 1935	2
Number of dry holes completed during 1935	650

Oil Production and Development in North Central Texas in 1935

By T. F. Petty*

(New York Meeting, February, 1936)

During 1935 there were drilled in North Central Texas 1071 wells, of which 565 were dry holes, 469 were oil wells with an initial production of 43,766 bbl. and 37 were gas wells with an initial production of 129,332,000 cu. ft. Production has been 14,180,042 bbl., or a daily average of 38,849 bbl. In Table 1 are listed the various pools of the district. Most of the smaller pools are of minor importance and are merely productive spots. Numerous other similar spots might have been listed as pools but their production is included in other fields. There are a few flowing wells but practically all of the wells are being pumped. The estimated potential is about 50,000 bbl. and the allowable production is based on the Texas Marginal Well Law.

In Table 2, wildcat wells that have resulted in the discovery of pools or important extensions to old pools or that have contributed to the geological information of the area are listed.

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* Humble Oil & Refining Co., Cisco, Texas.

TABLE 1.—*Oil and Gas Production in North Central Texas*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres	Total Oil Production, Bbl.			
			Oil	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
1	Bull-Alcom, *Brown*	8	100	113,238	10,121	6,271	13
2	Byler	9	290	793,280	65,260	20,822	42
3	Byrds Store	15	250	380,067	9,534	4,191	13
4	Childress	8	180	697,209	28,116	37,643	105
5	Clark-Buffalo	8	460	731,050	22,802	16,282	41
6	Cross-Cut	14	2,300	5,751,506	170,875	131,504	356
7	Fry	10	940	7,404,828	133,578	116,078	311
8	George	8	200	680,387	23,330	22,697	75
9	Smith-Ellis	9	450	2,110,535	37,019	41,939	120
10	Stover	9	1,500	6,484,692	221,465	195,654	495
11	Other Fields		5,595	2,249,746	99,518	111,480	232
12	Total Brown County		12,265	27,396,538	821,618	704,561	1,803
13	Baum, *Callahan*	10	500	809,117	37,065	28,790	84
14	Hatchett	8	375	1,113,691	86,013	64,623	178
15	Isenhour	12	600	1,969,714	66,684	63,570	159
16	Moutray	9	400	2,101,616	150,241	136,210	360
17	Other Fields		9,515	6,170,503	277,633	267,905	774
18	Total Callahan County		11,390	12,164,641	617,636	560,098	1,555
19	Burkett (Shallow), *Coleman*	11	850	2,016,666	121,391	97,185	271
20	Burkett (Deep)	5	200	624,275	64,951	34,421	73
21	Dibbrell	8	170	309,875	15,330	11,777	21
22	Eastland	7	270	1,837,650	64,689	56,444	164
23	Jennings	8	135	433,385	18,714	13,960	35
24	Overall	9	200	1,085,992	63,505	60,765	189
25	Santa Anna	13	150	390,959	12,901	12,202	32
26	Stewardson	5	200	341,100	34,159	34,388	98
27	Other Fields		985	1,510,279	99,557	142,965	360
28	Total Coleman County		3,160	8,550,181	496,197	464,107	1,243
29	Sipe Springs, *Comanche*	16	800	1,352,124	22,271	25,923	69
30	Hilburn, *Eastland*	16	400	1,080,648	10,400	7,066	17
31	Mangum	13	300	662,404	80,391	75,240	198
32	Pioneer	16	1,400	5,175,038	133,505	112,315	282
33	Ramsour	10	250	1,364,798	37,908	28,518	72
34	Other Fields		27,660	61,876,617	740,753	709,527	1,867
35	Total Eastland County		30,010	70,159,505	1,002,957	931,866	2,436
36	Desdemona, *Eastland, Erath, Comanche*	17	6,175	22,457,238	238,524	226,622	615
37	Howard, *Fisher*	1	40	10,755	0	10,755	121
38	Stephens (Royston)	7	2,880	6,134,375	1,625,413	1,982,552	5,542
39	Total Fisher County		2,920	6,145,130	1,625,413	1,993,307	5,663
40	Higgs (Sandy Ridge), *Jones*	10	110	65,827	2,254	25,228	95
41	Hawley (King)	10	320	186,107	22,915	63,776	530
42	Lueders	1	80	15,658	0	15,658	123
43	Noodle Creek	8	1,030	5,839,656	598,328	347,891	788
44	Sayles	3	320	244,515	27,838	192,988	567
45	Sellars	2	40	21,394	10,754	10,640	9
46	Other Fields		20	44,475	7,110	28,879	8
47	Total Jones County		1,920	6,417,622	669,199	685,060	2,120
48	Moody, *Haskell*	8	40	86,635	8,173	6,654	20
49	McCulloch, *McCulloch*	1	10	981	0	981	0
50	Dalton, *Palo Pinto*	14	160	334,452	4,665	0	0
51	Hart	15	600	750,669	3,697	0	0
52	Strawn	21	1,150	2,675,470	71,555	64,141	165
53	Other Fields		550	591,867	50,558	79,224	196
54	Total Palo Pinto County		2,460	4,352,458	130,475	143,365	361
55	McMillan, *Runnels*	9	190	774,465	372,493	190,585	413
56	Cook, *Shackelford*	10	1,460	12,840,850	801,973	891,325	2,672
57	Frye	10	115	289,178	13,139	10,758	29
58	Hope	12	220	1,082,498	67,476	75,519	194
59	Ibex	14	1,240	2,290,650	44,404	33,249	84
60	Bluff Creek (Morris)	5	940	851,401	288,649	303,484	985
61	Newell	10	640	498,313	128,000	140,723	323
62	Petroleum Producers	6	100	107,523	9,552	12,269	42
63	Simmons-Harvey	10	160	210,825	42,012	53,484	118
64	Tannehill-Matthews	8	300	1,812,869	121,100	141,005	410
65	Other Fields		7,705	8,565,093	1,297,465	1,360,464	1,170
66	Total Shackelford County		12,880	28,549,200	2,011,797	2,130,955	6,027
67	Curry, *Stephens*	15	2,580	9,136,425	114,011	111,128	312
68	Strawn	18	850	4,238,725	104,080	97,629	272

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.	Number of Oil and/or Gas Wells	Average Depth, Ft.	Character of Oil, Approx. Average during 1935		Producing Rock			
	Per Acre to End of 1935[b]	At End of 1935	Bottoms of Productive Wells	Gravity A.P.I. at 60° F.		Name	Age[g]	Character[h]	Structure[i]
		Total Producing		Maximum	Minimum				
1	1,132	11	1,150	44	40	Fry sand	Pen	S	ML, N
2	2,735	24	1,300	44	40	Fry sand	Pen	S	ML, N
3	1,520	6	2,450	39	37	Bend	Pen	L	A
4	3,873	65	800	34	33	Childress sand	Pen	S	ML, N
5	1,589	43	1,150	44	40	Fry sand	Pen	S	ML, N
6	2,501	223	1,200	44	40	Cross Cut sand	Pen	S	ML, N
7	7,877	130	1,300	44	40	Fry sand	Pen	S	ML, N
8	3,402	45	1,300	44	40	Fry sand	Pen	S	ML, N
9	4,690	58	1,300	44	40	Fry sand	Pen	S	ML, N
10	4,323	218	1,200	44	40	Blake sand	Pen	S	ML, N
11	402	389		44	30				
12	2,234	1,212		44	30				
13	1,618	41	1,700	44	40	Cross Plains sand	Pen	S	ML, N
14	2,970	94	400	36	34	Moutray sand	Pen	S	ML
15	3,283	126	700	36	34	Isenhour sand	Pen	S	ML
16	5,254	114	750	36	34	Moutray sand	Pen	S	ML
17	649	1,003		39	32				
18	1,069	1,278		39	32				
19	2,373	165	400	35	34	Burkett sand	Pen	S	ML
20	3,121	38	1,550	44	40	Cross Cut sand	Pen	S	ML, N
21	1,823	11	1,900	44	40	Gwinnup sand	Pen	S	ML, N
22	6,806	44	2,000	43	41	Gwinnup sand	Pen	S	ML, N
23	3,210	25	1,150	44	40	Fry sand	Pen	S	ML
24	5,430	30	2,200	44	40	Canyon and Strawn	Pen	S	A
25	2,606	9	1,500	44	40	Fry sand	Pen	S	ML, N
26	1,706	20	1,450	44	40	Fry sand	Pen	S	ML, N
27	1,533	58		44	34				
28	2,706	400		44	34				
29	1,690	100	300	37	34	Strawn	Pen	S	A
30	2,702	2	3,100	38	35	Bend	Pen	L	MN
31	2,208	46	1,200	y	y	Strawn	Pen	S	ML
32	3,696	58	2,450	42	38	Caddo lime	Pen	L	AF
33	5,459	9	3,600	39	37	Bond sand	Pen	S	N
34	2,242	408		42	y				
35	2,338	523		42	y				
36	3,640	108	2,750	39	37	Desdemona sand	Pen	S	A
37	269	2	3,670	36	35	y	Pen	L	A
38	2,130	86	3,100	41	38	Saddle Creek	Pen	L	A
39	2,104	88		41	35				
40	599	11	1,900	38	36	Petroleum Prod. sand	Pen	S	N
41	582	16	2,050	38	36	Petroleum Prod. sand	Pen	S	A
42	196	5	2,040	38	36	King sand	Pen	S	A
43	5,670	95	2,450	40	38	Camp Colorado	Pen	L	MC, N
44	764	13	1,950	38	36	Petroleum Producers sand	Pen	S	ML, N
45	535	4	1,950	38	36	Petroleum and Tannehill	Pen	S	ML, N
46	2,224	2		40	36				
47	3,811	148		40	36				
48	2,166	6	1,800	37	36	Hope sand	Pen	S	N
49	98	1	700	y	y	Canyon	Pen	S	N
50	2,090	12	3,950	y	y	Bend	Pen	L	N
51	1,251	4	3,200	y	y	Bend	Pen	L	N
52	2,327	151	1,850	y	y	Strawn sands	Pen	S	ML, N
53	1,076	32		y	y				
54	1,770	199		y	y				
55	4,076	19	2,550	48	43	McMillan sand	Pen	S	ML, N
56	8,795	350	1,300	38	37	Cook sand	Pen	S	ML, N
57	2,515	56	450	36	34	Fry sand	Pen	S	ML, N
58	4,920	49	1,500	39	37	Hope sand	Pen	S	ML, N
59	1,847	43	3,500	38	36	Caddo lime	Pen	L	N
60	906	94	1,600	40	38	Petroleum Prod. sand	Pen	S	ML, N
61	779	93	1,100	38	36	Tannehill sand	Pen	S	ML, N
62	1,075	11	1,650	40	38	Petroleum Prod. sand	Pen	S	N
63	1,318	10	1,700	40	38	Petroleum Prod. sand	Pen	S	N
64	6,043	67	1,150	41	39	Tannehill sand	Pen	S	ML, N
65	1,112	928		41	35				
66	2,217	1,701		41	35				
67	3,541	57	3,100	38	36	Caddo lime	Pen	L	A
68	4,986	101	1,850	39	y	Strawn sands	Pen	S	ML, N

[b] Footnotes to column heads and explanation of symbols are given on page 215.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres	Total Oil Production, Bbl.			
			Oil	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
69	Other Fields		44,570	107,221,393	1,791,663	1,612,192	4,205
70	Total Stephens County		48,000	120,596,543	2,009,754	1,820,949	4,789
71	Taylor, *Taylor*	7	170	188,598	39,839	35,013	105
72	Woodson (Deep), *Throckmorton*	11	260	1,629,943	147,764	86,294	203
73	Woodson (Shallow)	10	120	624,368	46,535	45,508	113
74	Other Fields		720	506,619	46,848	36,752	96
75	Total S/2, *Throckmorton*		1,100	2,760,930	241,147	169,554	412
76	Bunger, *Young*	14	1,040	3,594,523	89,333	80,746	197
77	Graham	9	380	1,612,663	54,234	54,342	111
78	Graham-Vic	5	320	204,909	*y*	*y*	506
79	Herron City	14	500	1,539,583	19,324	16,946	43
80	Kisinger	6	410	2,121,739	206,399	281,539	690
81	South Bend	18	1,440	9,878,308	176,027	159,178	447
82	Other Fields		4,510	32,840,194	3,048,580	2,807,687	8,122
83	Total Young County		13,349	51,791,919	3,953,897	3,605,347	10,116
84	Antelope, *Jack*	*y*	350	282,419	23,515	25,825	64
85	Bryson	*y*	600	3,341,683	287,952	258,558	693
86	Buttram	*y*	770	2,289,456	172,212	200,588	506
87	Buttram-Boyd	*y*	10	9,769	120	124	0
88	Total Jack County	*y*	1,730	5,932,327	483,679	485,095	1,263
89	Total		148,559	369,677,035	14,341,413	14,180,042	39,010

Line Number	Average Oil Production, Bbl.	Number of Oil and/or Gas Wells	Average Depth, Ft.	Character of Oil, Approx. Average during 1935		Producing Rock			
	Per Acre to End of 1935[b]	At End of 1935	Bottoms of Productive Wells	Gravity A.P.I. at 60° F.		Name	Age[g]	Character[h]	Structure[i]
		Total Producing		Maximum	Minimum				
69	2,406	581		39	36				
70	2,512	739		39	36				
71	1,109	11	2,500	38	36	Cisco	Pen	S, L	N
72	6,246	10	3,900	39	37	Caddo lime	Pen	L	A
73	5,203	11	2,350	38	36	Canyon, Strawn sand	Pen	S	ML
74	704	150		39	33				
75	2,510	171		39	33				
76	3,456	54	2,600	38	36	Strawn sand	Pen	S	A
77	4,244	10	3,900	38	36	Bend, Strawn	Pen	SL	A
78	640	14	2,750	38	36	Strawn sand	Pen	S	A
79	3,079	16	2,600	38	36	Strawn sand	Pen	S	ML, N
80	5,175	49	2,500	38	36	Strawn sand	Pen	S	A
81	6,860	77	4,000	38	36	Strawn, Bend	Pen	SL	ML, N
82	7,282	1,656		39	33				
83	3,805	1,877		40	30				
84	807	84	600	*y*	*y*	Cisco	Pen	S	N
85	5,569	70	4,800	*y*	*y*	Strawn	Pen	S	N
86	2,969	53	4,800	*y*	*y*	Strawn, Bend	Pen	SL	N
87	977		2,425	*y*	*y*	Strawn	Pen	S	N
88	2,450	207		*y*	*y*				
89	2,488	8,786		48	30				

TABLE 2.—*Summary of Drilling Operations in North Central Texas in 1935*

Important Wildcats Drilled in 1935

	County	Location: Section, Survey	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day: Oil, U.S. Bbl.	Initial Production per Day: Gas, Millions Cu. Ft.	Remarks
1	Brown	G. A. Parker	3434	Trinity (Com.)	Hickory (Cambrian)	McDonald & Campbell			Dry.
2	Callahan	68 B.B.B. & C.R.R.	1574	Clyde (Albany)	Harpersville (Cisco)	Suits Trustee	20		
3	Callahan	104 B.B.B. & C.R.R.	1245	Belle Plains (Albany)	Thrifty (Cisco)	Campbell et al.	10		
4	Callahan	141 B.B.B. & C.R.R.	930	Belle Plains (Albany)	Moran (Cisco)	Schuman Syndicate	15		
5	Fisher	180 H. & T.C.R.R. Blk. 2	3677	Double Mountain (Perm.)	Thrifty (Cisco)	Merry Bros. & Perini & Tidewater	185		
6	Hamilton	I. Adams	3744	Walnut (Com.)	Ellenberger (Ord.)	P. K. Oneal			Dry.
7	Jones	207 B.B.B. & C.R.R	2041	Clear Fork (Perm.)	Graham (Cisco)	Farris & Fikes	1025		
8	Shackelford	4 T. & N.O.	1623	Clyde (Albany)	Harpersville (Cisco)	Reliance-Jones & Stasney	60		
9	Shackelford	137 E.T.R.R.	1518	Clyde (Albany)	Harpersville (Cisco)	Reliance-Jones & Stasney	89		
10	Shackelford	167 E.T.R.R.	1306	Clyde (Albany)	Moran (Cisco)	Texas Central-Rhodes & Slicker	25		
11	Shackelford	150 E.T.R.R.	1550	Clyde (Albany)	Harpersville (Cisco)	Humble Oil & Ref. Co.	48		
12	Shackelford	207 E.T.R.R.	1597	Clyde (Albany)	Harpersville (Cisco)	Charter Oil Co.	30		
13	Shackelford	1549 T.E.&.L.	4466	Moran (Cisco)	Ellenberger (Ord.)	Pitzer & West	336		Junked casing shot off.
14	Throckmorton	163 B.B.B. & C.R.R.	5496	Belle Plains (Albany)	Ellenberger (Ord.)	Humble Oil & Ref. Co.			Dry.
15	Young	1104 T.E. & L.	3950	Graham (Cisco)	Bend lime	Pitzer & West	100		
16	Young	J. G. Holly	4090	Thrifty (Cisco)	Bend sand	Rathke (Seddon)	1320	6	
17	Young	J. G. Holly	3805	Thrifty (Cisco)	Bend lime	Rathke (Rodgers)	723		
18	Roberts	W. Fullerton	3692	Graham (Cisco)	Bend lime	Roberts Oil Corp.	408		

	In Proven Fields and Wildcats
Number of wells drilling Dec. 31, 1935	140
Number of oil wells completed during 1935	469
Number of gas wells completed during 1935	37
Number of dry holes completed during 1935	565

Oil and Gas Development in the Texas Panhandle for the Year 1935

By T. C. Craig*

(New York Meeting, February, 1936)

During the year, there were 570 oil wells completed for a total daily initial production of 365,352 bbl. The daily oil potential of the field, effective Jan. 1, 1935, as established by the Texas Railroad Commission, was 306,102 bbl. with a daily allowable of 58,800 bbl., whereas, on Dec. 31, 1935, the potential was 587,376 bbl. with a daily allowable of 57,800 bbl. Because of the limited market demand, the allowable decreased although the potential increased. In August, the five-day test for determining the potential production of a well was replaced by a 24-hr. test. The reason for this change was that some of the oil-purchasing companies contended that too much oil in excess of the limited market demand was produced during the five-day tests.

Dry Gas.—During July, the Texas Railroad Commission supervised the first complete and accurate field-wide test of open flows that has been made in this area. The total open flow as determined at that time was 16,426,085,000 cu. ft. There were 79 gas wells drilled in 1935, with a combined open flow of 2,408,000,000 cu. ft. and 50 depleted oil wells were plugged back for gas with a total open flow of 529,800,000 cu. ft. The total new gas production for the year was, therefore, 2,937,800,000 cu. ft.

The 17 natural-gas pipe lines drawing on the Panhandle supply of fuel gas withdrew a daily average of 420,497,507 cu. ft., or a total of 153,481,590,000 cu. ft. for the year.

The 44th Texas Legislature passed a statute known as House Bill No. 266, which was designed to prohibit waste and protect correlative rights by compelling the ratable production of gas. The part of the law relative to withdrawal of sweet gas became effective Aug. 1, 1935, and the part referring to withdrawal of sour gas became effective Oct. 1, 1935. Three of the major pipe line companies attacked the validity of the ratable production feature of the new law and a preliminary injunction was granted by the Federal District Court. The final hearing on the merits of the case is scheduled for the early part of January.

Natural Gasoline.—Forty of the 42 natural-gasoline extraction plants in the Panhandle operated throughout the year. One plant discontinued

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operations in August and another was shut down for a period of one month. The combined total capacity of these natural-gasoline plants is approximately 2,574,000,000 cu. ft. per day, or 929,510,000,000 cu. ft. per year. The total amount of gas processed by all plants during the year was 595,922,523,000 cu. ft. The total gasoline produced was 118,165,-389 gal. In addition to these plants, there are four absorber plants,

TABLE 1.—*Oil and Gas Production in Texas Panhandle*

Line Number	County	Age in Years to End of 1935	Area Proved, Acres		
			Oil and Gas[a]	Gas	Total
1	Carson	14	15,000	235,314	250,314
2	Gray	10	39,800	209,957	249,757
3	Hartley	7	0	29,984	29,984
4	Hutchinson	13	49,000	192,495	241,495
5	Moore	9	2,000	429,827	431,827
6	Potter	16	0	143,194	143,194
7	Wheeler	10	8,200	149,615	157,815
8	Total		114,000	1,390,386	1,504,386

[a] Footnotes for column heads and explanation of symbols are given on p. 215.

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.		Total Gas Production, in Millions of Cubic Feet			
	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935
1	23,088,407	1,910,765	1,774,395	4,918	1,539	16.9				
2	112,947,309	12,302,087[1]	11,200,522	29,871	2,838	23.1				
3, 4	108,357,981	4,450,476	4,617,574	13,721	2,211	17.2				
5	2,853,497	321,677	465,915	1,103	1,427	58.0				
6	33,822									
7	6,744,583	1,368,945	3,480,665	11,566	823	44.3				
8	254,025,599	20,353,950	21,539,071	61,179			5,436,063.6[2]	715,268.5[2]	805,884.1[2]	2,600.0[2]

[1] Error of 8,000,000 bbl. in Gray County production for 1934 as given last year is corrected in this report.
[2] Gas figures are composite for field, they are the best available but are subject to correction.

which also extract gasoline from the gas to be transported by gas pipe line companies. No figures are available to the writer, however, giving the amount of gasoline extracted by these plants.

Carbon Black.—There are 29 carbon-black plants in the Texas Panhandle. Twenty-eight are the channel type and one is thermo-atomic. The combined daily capacity of these plants is approximately 656,350,-

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells							Average Depth, Ft.		Oil Production Methods at End of 1933						Pressure, Lb. per Sq. In.[e]		
		During 1935		At End of 1935						Number of Wells							Average at End of	
Line Number	Completed to End of 1935	Completed	Abandoned	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Misc.	Injection into Reservoir[d]	Initial	1934	1935[3]
1	553	53	4	90	203	224	517	3,150	3,050	y	y	y	y	y		430	y	359.13
2	1,597	273	10	618	703	180	1,501	3,100	3,000	y	y	y	y	y		430	y	307.01
3	4	0		0	0	4	4	3,200	2,900							430	y	415.00
4	1,550	136	42	514	293	205	1,012	3,000	2,900	y	y	y	y	y		430	y	303.89
5	131	31	0	4	16	102	122	3,500	3,400	y	y	y	y	y		430	y	405.72
6	44	2		0	0	44	44	2,500	2,300							430	y	414.11
7	562	154	1	97	181	273	551	2,550	2,450	y	y	y	y	y		430	y	374.53
8	4,441	649	57	1,323	1,396	1,032	3,751											

[3] Weighted average rock pressure based on 1,504,386 acres as total area of field (both proven and semiproven). Compilation made by Texas Railroad Commission, July, 1935.

	Character of Oil Approx. Average during 1935					Character of Gas Approx. Average during 1935		Producing Rock				Deepest Zone Tested to End of 1935	
	Gravity A.P.I. at 60° F.												
Line Number	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.[4]	Gal. Gasoline per M. Cu. Ft.[4]	Name	Age[g]	Character[h]	Structure[i]	Name	Depth of Hole, Ft.
1	45	32	39	0.6	M	1,094	0.43	Big Lime series (Wichita-Albany) Pen undifferentiated	Per Pen	D, Da GW	Af	Granite Wash (Pen)	
2	45	31	39	0.4	M	1,103	0.70	Big Lime series (Wichita-Albany) Pen undifferentiated	Per Pen	D, Da GW	Af	Granite Wash (Pen)	
3								Big Lime series (Wichita-Albany)	Per	D	Af	Granite Wash (Pen)	
4	39	29	35	0.8	M	1,106	0.47	Big Lime series (Wichita-Albany) Pen undifferentiated	Per Pen	D, Da L, GW	Af	Arbuckle	5,333
5	36	30	31	0.8	M	1,056	0.30	Big Lime series (Wichita-Albany) Pen undifferentiated	Per Pen	D L, GW	Af	Arbuckle	8,013
6						1,069		Big Lime series (Wichita-Albany) Pen undifferentiated	Per Pen	D GW	Af	Granite Wash (Pen)	
7	44	30	37	0.4	M	1,070	0.28	Big Lime series (Wichita-Albany) Pen undifferentiated	Per Pen	D, Da GW	Af	Arbuckle	2,957
8													

[4] Dry gas, 30 in. at 60° F.

000 cu. ft. During the past year, 190,621,250,000 cu. ft. of gas was processed. The average yield of carbon black is approximately 1.43 lb. per 1000 cu. ft. of gas, which gives a total of 272,588,387 lb. of black for the year's production.

Refineries.—The total daily capacity of the Panhandle refineries was approximately 75,250 bbl. Of these refineries, plants having an approximate capacity of 8500 bbl. were not operated. The total oil run to local refineries during the year was 11,426,136 barrels.

Storage.—The total storage capacity for the field was 21,882,500 bbl. on Jan. 1, 1935, and on Dec. 31, 1935, it was 21,612,500 bbl. There were 13,905,567 bbl. of oil in storage on Jan. 1, 1935. Net withdrawal of

TABLE 2.—*Summary of Drilling Operations in Texas Panhandle*

Important Wildcats Drilled in 1935

	County	Location: Sec.	Location: Block	Location: Survey	Total Depth, Ft.	Surface Formation
1	Dallam	2	2	B. and B.	4225	Tertiary
2	Childress	417	H	W. and NW.	8223	Blaine
3	Childress	27	9	H. and GN.	5385	Blaine
4	Childress	14	9	H. and GN.	4525	Blaine
5	Collingsworth	6	13	H. and GN.	2216	Blaine
6	Collingsworth	19	17	H. and GN.	2300	Blaine
7	Collingsworth	108	21	H. and GN.	2830	Quaternary

	Deepest Horizon Tested	Drilled By	Initial Production Per Day: Gas Millions Cu. Ft.	Pressure, Lb. per Sq. In.: Casing	Remarks
1		Eben Warner			Dry and abandoned
2	Ellenberger	Alma Oil Co.			Dry and abandoned. Had good show oil in Pennsylvanian
3	Ellenberger	Humble Oil & Refining Co.			Dry and abandoned
4	Granite Wash (Penn)	Humble Oil & Refining Co.			Dry and abandoned
5	Granite Wash (Penn)	Anderson-Kerr			Dry and abandoned
6	Granite Wash (Penn)	Tom Hunter et al.	1.8	400	
7	Brown Dolomite (Per)	Smith Bros.			Dry and abandoned

	In Proven Fields
Number of wells drilling Dec. 31, 1935	175
Number of oil wells completed during 1935	570
Number of gas wells completed during 1935	79
Number of dry holes completed during 1935	29

1,394,178 bbl. reduced the oil in storage on Dec. 31, 1935, to 12,511,389 barrels.

New Development.—No discoveries of particular consequence were made during the year. The major part of the drilling for oil production was on inside locations.

A small granite wash pool, known as the Bell area, was discovered on the south side of the granite ridge in Gray County. The wells now producing oil are in secs. 79, 101 and 110, block B-2, H. & GN. survey. Present indications are that the pool is of small areal extent.

In Wheeler County, about 4 miles northwest of the Osborne area, a small granite wash pool discovered last year, a small group of wells obtained production from the arkosic dolomite. This new pool, known as the Teci area, is in secs. 72, 73 and 89 of block 13, H. & GN. survey.

Production along the brown dolomite trend in Hutchinson County was extended approximately 3 miles to the northwest by a well drilled within the Stinnett townsite.

An extensive exploratory drilling program was started in Moore County during the summer. With the exception of a small area between the Brumley and Sunray pools, gas is the only production to date. Whether or not this small oil pool will be extended into a definite producing trend is unknown at present.

Wildcats.—Seven wildcat wells were completed during the year, all of which were dry. Childress County had three completions, two of which encountered the Ellenberger dolomite. Collingsworth County also had three completions, all of which were granite wash tests. A well was drilled in Dallam County to an estimated total depth of 4225 feet, but no information concerning the formations penetrated was available. Randall, Hall and Hartley counties each had a deep test drilling as the year closed.

Oil and Gas Development in Southwest Texas during 1935

By Olin G. Bell,* Member A.I.M.E.

(New York Meeting, February, 1936)

At the beginning of the year 1935 the older fields in Southwest Texas, and particularly those discovered during 1934, had been practically delimited and only normal development continued. As a result, operations in this area were somewhat slowed down.

Shortly after the first of the year, however, activity in the area was greatly accelerated, due largely to the fact that the Loma Novio field, discovered during the last few days of 1934, indicated the presence of a new productive trend east of and parallel to the Government Wells field and also indicated the presence of a new productive horizon, the Loma Novio sand, approximately 100 ft. lower than the Government Wells sand zone. Other discoveries during the year greatly augmented the activity in the district.

During the year there were 651 oil wells, 53 gas wells and 275 dry holes drilled in this area during the year. Most of the operations were in the Government Wells, Cole, Loma Novio, Seven Sisters and Lopez fields.

New Fields

Four new fields were discovered during 1935 as follows: Seven Sisters and Piedra de Lumbre in Duval County; Loma Alto in McMullen County; and Lopez in Webb County.

Seven Sisters Field.—The Seven Sisters field, opened in May, was the direct result of a systematic search for new productive areas northeast of the Loma Novio field. The first producer, Harvey & Henderson No. 1 Chernosky, survey 226, was completed in the Labbé (Chernosky) sand at 2220 ft. However, the second producer, Santa Clara Oil Co. No. 1 Welder in survey 385, drilled about one mile south of the discovery well, failed to find production in the Labbé sand and was carried on down and completed in the Government Wells sand at 2473 ft. with an initial production of 20 bbl. of oil per hour. These two discoveries, in the Labbé and Government Wells sand, started an active leasing and drilling campaign in this part of Duval County and drilling operations continued especially active throughout the remainder of the year.

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TABLE 1.—*Oil and Gas Production in Southwest Texas*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres			Total Oil Production, Bbl.				Average Oil Production, Bbl.		
			Oil	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Dec., 1935	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Dec., 1935
1	Reiser, *Webb*	27	0	1,280	1,280	Gas	Gas	Gas	0	0	0	0
2	Charco Redondo, *Zapata*	22	336	0	336	138,672	4,415	2,579	7	412.7	51.6	0.04
3	Jennings, *Zapata*	21	0	320	320	Gas	Gas	Gas	0	0.0	0.0	0
4	Crowther, *McMullen*	16	160	0	160	*x*	0	0	0	0	0	0
5	Calliham, *McMullen*	16	300	290	590	514,267	15,318	31,276	132	871.6	67.0	3.0
6	Mirando Valley, *Zapata*	14	115	120	235	623,504	10,684	10,476	21	2,653.2	176.9	1.0
	Carolina-Texas, *Webb*											
7	1,200-ft. sand	14	0	80	80	Gas	Gas	Gas	0	0	0	0
8	2,000-ft. sand	13	0	480	480	Gas	Gas	Gas	0	0	0	0
9	2,600-ft. sand	10	70	480	550	90,247	10,483	4,818	16	164.0	20.0	4.0
10	3,000-ft. sand	12	40	400	440	156,546	15,398	3,258	18	355.8	19.7	2.5
11	5,000-ft. sand	1	0	40	40	Gas	Gas	Gas	0	0	0	0
12	Total		110	1,480	1,590	246,793	25,881	8,076	34			
13	Mirando City, *Webb*	14	1,430	420	1,850	8,461,891	163,100	137,821	348	4,573.9	415.8	3.0
14	Aviator, *Webb*	13	955	320	1,275	5,385,469	174,844	154,718	391	4,223.9	384.0	4.2
15	Leaseholders, *Webb*	13	10	0	10	Not Available	0	0	0	0	0	0.0
16	Henne-Winch-Fariss, *Jim Hogg*	11	720	440	1,160	3,202,298	11,865	7,160	3	2,760.6	306.7	0.5
	Cole, *Webb*											
17	1,700-ft. sand	11	65	4,000	4,065	167,656	15,085	12,288	33	41.2	2.3	5.5
18	2,300-ft. sand	8	0	1,280	1,280	Gas	Gas	Gas	0	0	0	0.0
19	2,800-ft. sand	5	600	120	720	656,081	51,936	326,242	1,895	910.5	91.0	33.8
20	2,900-ft. sand	1	0	80	80	Gas	Gas	Gas	0	0	0	0.0
21	3,400-ft. sand	1	640	80	720	1,275,976	109,563	1,138,413	2,721	1,772.2	126.6	48.6
22	Total		1,305	5,560	6,865	2,099,713	176,584	1,476,943	4,649			
23	Randado, *Jim Hogg*	10	733	150	883	4,244,915	139,072	132,476	333	4,807.4	534.4	3.0
24	Piedras Pintas, *Duval*	10	30	0	30	142,021	18,531	12,129	65	4,734.0	236.7	32.0
25	Alworth, *Jim Hogg*	9	40	30	70	26,977	1,214	1,151	0	385.4	64.2	0.0
26	Kohler, *Duval*	9	170	1,840	2,010	465,858	48,276	44,012	94	231.7	33.1	11.7
27	West Cole, *Webb*	8	330	960	1,290	3,087,793	240,292	286,083	1,005	2,703.7	245.8	17.6
28	Cuellar, *Zapata*	8	315	160	475	2,403,938	50,990	42,146	113	5,060.9	632.6	3.7
	Driscoll, *Duval*											
29	2,400-ft. sand	8	0	600	600	Gas	Gas	Gas	0	0	0	0
30	2,900-ft. sand	7	200	400	600	429,744	26,517	20,444	100	716.2	119.4	25.6
31	3,300-ft. sand		150	400	550	79,400	17,240	62,310	148	144.3	14.4	49.0
32	Total		350	1,400	1,750	509,144	43,757	82,754	248			
33	Albercas, *Webb*	7	320	160	480	2,407,721	51,030	38,246	92	5,016.1	296.2	3.0
34	Government Wells, *Duval*	7	7,840	350	8,190	22,544,767	6,550,438	6,393,169	16,697	2,752.7	144.9	23.4
35	Palangana, *Duval*	7	20	0	20	3,631	0	0	0	181.5	36.3	0
36	Martinez, *Zapata*	7	0	600	600	Gas	Gas	Gas	0	0	0	0
37	Roma, *Starr*	6	10	80	90	8,327	2,252	2,355	2	92.5	3.0	2
	Escobas, *Zapata*											
38	1,000-ft. sand	5	0	120	120	Gas	Gas	Gas	0	0	0	0
39	1,200-ft. sand	6	1,400	90	1,490	4,343,967	671,399	604,164	1,558	2,915.4	182.2	7.3
40	1,400-ft. sand	5	1,800	120	1,920	1,221,103	111,109	62,761	135	635.9	90.8	2.4
41	Total		3,200	330	3,530	5,565,070	782,508	666,925	1,693			
42	S. R. C., *Duval*	5	80	0	80	199,509	34,417	15,937	13	2,493.8	356.2	0
43	Los Olmos, *Starr*	4	160	0	160	419,321	93,632	71,742	142	2,620.8	238.2	1.7
44	Wentz, *McMullen*	3	0	80	80	Gas	Gas	Gas	0	0	0	0
45	Sarnosa, *Duval*	3	620	40	660	1,205,140	336,636	320,323	881	1,801.7	45.0	19.5
46	Rio Grande City, *Starr*	3	90	0	90	146,337	24,385	72,514	194	1,625.9	203.2	11.4
47	Jacobs, *McMullen*	3	1,000	10	1,010	551,268	203,878	180,315	404	545.8	28.7	6.8
48	Laurel, *Webb*	3	220	320	540	587,822	79,982	32,262	44	1,088.5	120.9	2.5
49	Villa, *Zapata*	3	0	80	80	Gas	Gas	Gas	0	0	0	0
50	Clark-Cowden, *Jim Hogg*	3	80	40	40	Gas	Gas	Gas	0	0	0	0
51	Smith-Hunter, *Duval*	3	0	40	40	Gas	Gas	Gas	0	0	0	0
52	Moca, *Webb*	3	80	0	80	445,365	115,855	228,931	633	5,567.0	506.0	57.5
53	Blas Uribe, *Zapata*	2	0	80	80	Gas	Gas	Gas	0	0	0	0
54	Ignacio, *Duval*	2	10	0	10	Not Available	0	0	0	0	0	0
55	Cuevitas, *Starr*	2	360	400	760	229,684	73,297	154,327	372	302.2	13.7	41.3
56	Hoffman, *Duval*	2	20	30	50	5,486	0	5,486	160	109.7	18.3	80.0

[b] Footnotes to table headings and explanation of symbols are given on page 215.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions of Cubic Feet				Number of Oil and/or Gas Wells							Average Depth, Ft.		Character of Oil, Approx. Average during 1935		
						During 1935		At End of 1935						Gravity A.P.I. at 60° F.		
	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Weighted Average	Sulfur, Per Cent	Base[f]
1	*y*	0.0	0.0	0.0	15	0	0	0	0	0	0	800	650	0	0	0
2	0	0	0	0.0	155	0	0	0	147	0	147	173	165	16.0	0	0
3	*y*	285.2	403.0	*y*	25	0	0	0	0	2	2	1,240	1,220	0	0	0
4	0	0.0	0.0	0	*y*	0	0	0	0	0	0	*y*	*y*	*y*	0	*y*
5	*y*	*y*	*y*	*y*	43	4	0	0	41	2	43	1,000	700	19.5	*y*	*y*
6	*y*	10.4	13.3	*y*	29	1	0	0	18	1	19	1,540	1,525	22.5	*y*	2
7	*y*	0.0	0.0	0.0	2	0	0	0	0	0	0	1,305	1,270	0	0	0
8	*y*	*y*	*y*	*y*	24	0	0	0	0	0	0	2,130	2,120	0	0	0
9	*y*	*y*	*y*	*y*	18	0	6	0	4	6	10	2,605	2,597	34.0	*y*	*y*
10	*y*	*y*	*y*	*y*	18	1	0	0	7	10	17	3,198	3,180	46.0	*y*	*y*
11	*y*	0	*y*	*y*	1	1	0	0	0	1	1	5,056	4,957			
12	*y*	1,247.5	946.0	*y*	63	2	6	0	11	17	28					
13	*y*	1.2	1.9	*y*	294	0	0	0	113	1	114	1,741	1,730	22.5	*y*	2
14	*y*	0.0	0.0	0	217	0	105	0	92	0	92	1,730	1,719	22.5	*y*	2
15	0	0.0	0.0	0	2	0	0	0	0	0	0	1,015	1,000	18.0	*y*	*x*
16	*y*	0.0	0.0	0	191	0	6	0	6	0	6	2,149	2,140	22.5	*y*	2
17	*y*	*y*	*y*	*y*	123	0	0	0	6	82	88	1,730	1,722	22.5	*y*	2
18	*y*	*y*	*y*	*y*	32	0	0	0	0	22	22	2,324	2,314	0	0	0
19	*y*	*y*	*y*	*y*	61	56	0	0	56	0	56	2,810	2,800	22.5	*y*	2
20	*y*	*y*	*y*	*y*	2	0	0	0	0	2	2	2,960	2,951	0	0	0
21	*y*	*y*	*y*	*y*	58	37	2	0	56	0	56	3,414	3,400	41.7	*y*	*y*
22	*y*	9,409.7	7,880.0	0	316	93	2	0	118	106	224					
23	*y*	13.1	4.2	0	189	0	5	0	110	0	110	1,229	1,220	22.5	*y*	2
24	0	0.0	0.0	0	4	0	0	0	2	0	2	3,626	3,600	52.0	*y*	*y*
25	0	0.0	0.0	0	8	0	4	0	0	0	0	1,026	1,020	22.5	*y*	2
26	*y*	2,118.4	1,499.7	0	65	0	0	0	8	29	37	1,850	1,843	22.5	*y*	2
27	*y*	583.9	369.1	0	118	11	16	0	57	14	71	2,346	2,335	22.5	*y*	2
28	*y*	0.0	0.0	0	80	0	1	0	30	0	30	1,340	1,332	22.5	*y*	2
29	*y*	*y*	*y*	*y*	3	0	0	0	0	3	3	2,465	2,459	0	0	0
30	*y*	*y*	*y*	*y*	6	1	0	0	4	1	5	2,890	2,884	22.5	*y*	2
31	*y*	*y*	*y*	*y*	3	1	0	0	3	1	4	3,[illegible]48	3,370	0	0	0
32	944.7	177.9	404.2	*y*	12	2	0	0	7	5	12					
33	*y*	0.0	0.0	0.0	79	0	2	0	30	0	30	2,175	2,158	22.5	*y*	2
34	*y*	340.6	1,953.7	0	779	90	6	0	714	15	729	2,350	2,331	22.5	*y*	2
35	0	0	0	0	4	0	0	0	0	0	0	550	540	16.0	*y*	*y*
36	*y*	2,496.0	2,920.6	0	31	4	0	0	0	18	18	1,870	1,860	0	0	0
37	0	0	0	0	2	0	0	0	1	0	1	3,590	3,560	35.2	*y*	*y*
38	*y*	*y*	*y*	*y*	2	0	2	0	0	0	0	1,012	1,000	0	0	0
39	*y*	*y*	*y*	*y*	220	25	7	0	213	13	226	1,240	1,226	22.5	*y*	2
40	*y*	*y*	*y*	*y*	69	0	0	0	56	0	56	1,440	1,433	22.5	*y*	2
41	*y*	217.9	58.2	*y*	291	25	9	0	269	13	282					
42	0	0	0	0	6	0	5	0	0	0	0	1,727	1,720	22.5	*y*	2
43	0	0	0	0	82	8	0	0	72	0	72	380	369	18.0	*y*	*y*
44	*y*	*y*	*y*	*y*	2	0	0	0	0	2	2	380	370	0	0	0
45	27.5	0	0	0	48	18	11	0	45	3	48	2,455	2,415	22.5	*y*	2
46	0	0	0	0	19	12	1		17	0	17	1,463	1,455	27.3	*y*	*y*
47	0	0	0	0	67	21	6	0	59	0	59	975	956	22.0	*y*	*y*
48	790.3	288.7	264.6	*y*	24	0	4	0	17	3	20	2,220	2,211	48.5	*y*	*y*
49	0	0	0	0	2	0	0	2	0	0	2	1,600	1,580	0	0	0
50	0	0	0	0	1	0	0	1	0	0	1	2,262	2,246	0	0	0
51	0	0	0	0	1	0	0	1	0	0	1	1,931	1,910	0	0	0
52	0	0	0	0	13	0	0	0	11	0	11	861	850	22.5	*y*	0
53	0	0	0	0	3	1	0	3	0	0	3	1,845	1,835	0	0	0
54	0	0	0	0	2	0	0	2	0	0	2	2,138	2,127	22.5	*y*	2
55	10.4	10.4	0	0	17	0	0	0	9	6	15	2,242	2,220	35.2	*y*	*y*
56	0	0	0	0	5	1	1		2	2	4	2,757	2,751	0	0	0

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1935		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1	*y*	*y*	Cockfield	Eoc	Ss	Por	50	A	51	Mt. Selman	3,138
2	0	*y*	McElroy	Eoc	Ss	Por	8	M	30	Cockfield	3,000
3	*y*	0	McElroy	Eoc	Ss	Por	20	A	14	Recklaw	5,000
4	0	0	Cockfield	Eoc	Ss	Por	*y*	*x*	*x*	*y*	*y*
5	*y*	0	Cockfield	Eoc	Ss	Por	13	*x*	*x*	Cook Mountain	2,860
6	*y*	0	McElroy	Eoc	Ss	Por	15	ML	69	Cook Mountain	3,660
7	*y*	0	Whitsett	Eoc	Ss	Por	35	AF	0	Queen City	5,057
8	*y*	0	McElroy	Eoc	Ss	Por	10	AF	6	Queen City	5,057
9	*y*	0	Cockfield	Eoc	Ss	Por	8	AF	10	Queen City	5,057
10	*y*	0	Upper Saline Bayou	Eoc	Ss	Por	18	AF	17	Queen City	5,057
11								AF	0	Queen City	5,057
12											
13	*y*	0	McElroy	Eoc	Ss	Por	11	ML	95	Recklaw	5,000
14	*y*	0	McElroy	Eoc	Ss	Por	11	MF	69	McElroy	2,400
15	0	0	McElroy	Eoc	Ss	Por	15	ML	15	Cockfield	2,791
16	*y*	0	McElroy	Eoc	Ss	Por	9	MF	43	Cockfield	3,400
17	*y*	0	Whitsett	Eoc	Ss	Por	18	AM	32	Recklaw	6,394
18	*y*	0	McElroy	Eoc	Ss	Por	10	A	27	Recklaw	6,394
19	0	0	McElroy	Eoc	Ss	Por	10	A	6	Recklaw	6,394
20	*y*	0	Cockfield	Eoc	Ss	Por	9	A	13	Recklaw	6,394
21	*y*	0	Upper Saline Bayou	Eoc	Ss	Por	14	A	13	Recklaw	6,394
22											
23	*y*	0	Whitsett	Eoc	Ss	Por	9	MF	28	Mt. Selman	5,222
24	0	0	Cockfield	Eoc	Ss	Por	20	Ds	26	Mt. Selman	4,502
25	0	0	McElroy	Eoc	Ss	Por	6	ML	15	McElroy	2,500
26	*y*	0	Whitsett	Eoc	Ss	Por	7	MF	85	Mt. Selman	7,723
27	*y*	0	McElroy	Eoc	Ss	Por	11	ML	17	Mt. Selman	5,225
28	*y*	0	McElroy	Eoc	Ss	Por	8	ML	24	Mt. Selman	4,532
29	*y*	0	Whitsett	Eoc	Ss	Por	6	A	1	Caddell	3,448
30	*y*	0	McElroy	Eoc	Ss	Por	6	A	0	Caddell	3,448
31	*y*	0	Caddell	Eoc	Ss	Por	10	A	1	Caddell	3,448
32											
33	*y*	0	McElroy	Eoc	Ss	Por	17	MF	79	Lower Saline Bayou	4,942
34	*y*	0	McElroy	Eoc	Ss	Por	19	MF	41	Mt. Selman	5,858
35	0	0	Cap Rock	*x*	L	Cav	5	Ds	66	Jackson	3,813
36	*y*	0	McElroy	Eoc	Ss	Por	10	*x*	20	Cockfield	3,000
37	*y*	0	Queen City	Eoc	Ss	Por	30	A	5	Recklaw	4,827
38	*y*	0	McElroy	Eoc	Ss	Por	12	ML	0	Cockfield	3,500
39	*y*	0	McElroy	Eoc	Ss	Por	16	ML	15	Cockfield	3,500
40	*y*	0	McElroy	Eoc	Ss	Por	7	ML	29	Cockfield	3,500
41											
42	*y*	0	McElroy	Eoc	Ss	Por	7	MF	6	McElroy	2,400
43	*y*	0	Frio	Olig	Ss	Por	11	ML	65	McElroy	2,500
44	*y*	0	Whitsett	Eoc	Ss	Por	20	*x*	2	McElroy	2,000
45	*y*	0	McElroy	Eoc	Ss	Por	40	MF	14	McElroy	2,800
46	*y*	0	Frio	Olig	Ss	Por	8	*x*	17	McElroy	2,429
47	0	0	Cockfield	Eoc	Ss	Por	19	*x*	18	Cockfield	1,085
48	*y*	0	Cockfield	Eoc	Ss	Por	9	MF	29	Mt. Selman	3,225
49	0	0	McElroy	Eoc	Ss	Por	20	*x*	0	Cook Mt.	3,000
50	0	0	McElroy	Eoc	Ss	Por	16	*x*	5	McElroy	3,210
51	0	0	Frio	Olig	Ss	Por	21	*x*	2	Caddell	3,600
52	0	0	McElroy	Eoc	Ss	Por	11	AF	6	Upper Saline Bayou	2,178
53	*y*	0	McElroy	Eoc	Ss	Por	10	*x*	6	McElroy	3,000
54	*y*	0	McElroy	Eoc	Ss	Por	11	*x*	3	Caddell	3,102
55	*y*	0	McElroy	Eoc	Ss	Por	22	MF	13	Cockfield	3,600
56	*y*	0	McElroy	Eoc	Ss	Por	6	*x*	3	Cockfield	3,512

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1935	Total Oil Production, Bbl.: During 1934	Total Oil Production, Bbl.: During 1935	Total Oil Production, Bbl.: Daily Average during Dec., 1935	Average Oil Production, Bbl.: Per Acre to End of 1935[b]	Average Oil Production, Bbl.: Per Acre-foot to End of 1935	Average Oil Production, Bbl.: Per Well Daily during Dec., 1935
	North Kohler, *Duval*											
57	1,700-ft. sand	2	0	80	80	Gas	Gas	Gas	0	0	0	0
58	2,400-ft. sand	2	10	320	330	Gas	Gas	Gas	0	0	0	0
59	Total		10	400	410							
	Barbacoas, *Starr*											
60	900-ft. sand	1	0	20	20	Gas	Gas	Gas	0	0	0	0
61	2,400-ft. sand	2	20	160	180	18,572	3,571	15,001	23	103.2	6.9	11.5
62	Total		20	180	200	18,572	3,571	15,001	23		6.9	
	Eagle Hill, *Duval*											
63	1,500-ft. sand	2	200	0	200	353,633	179,985	155,006	376	1,768.0	176.8	20.8
64	2,100-ft. sand	1	40	0	40	15,176	5,969	9,217	36	379.4	37.9	18.0
65	Total		240	0	240	368,809	185,954	164,223	412			
66	Lopeño, *Zapata*	1	0	1,000	1,000	Gas	Gas	Gas	0	0	0	0.0
67	Comitas, *Zapata*	1	60	0	60	3,387	549	2,838	8	56.4	7.0	1.0
68	Labbé, *Duval*	1	0	40	40	Gas	Gas	Gas	0	0	0	0.0
69	Colmena, *Duval*	1	0	40	40		Gas	Gas	0	0	0	0.0
70	Loma Novio, *Duval*	1	3,500	170	3,670	782,644	0	782,644	6,676	213.2	30.4	31.7
71	Piedra de Lumbre, *Duval*	0	80	0	80	7,714	0	7,714	65	96.4	·	32.5
	Seven Sisters, *Duval*											
72	2,200-ft. sand	0	40	10	50	11,127	0	11,127	30	222.5	22.2	10.0
73	2,400-ft. sand	0	500	10	510	115,536	0	115,536	1,406	226.5	11.3	38.0
74	Total		540	20	560	126,663	0	126,463	1,436			
75	Loma Alto, *McMullen*	0	20	0	20	12,385	0	12,385	68	619.2	51.6	34.0
76	Lopez, *Webb*	0	640	0	640	62,737	0	62,737	797	98.0	4.9	30.6
77	Total		26,549	19,260	45,809	67,255,612	9,663,207	11,786,337	38,255			

Line Number	Total Gas Production, Millions of Cubic Feet: To End of 1935	Total Gas Production: During 1934	Total Gas Production: During 1935	Total Gas Production: Maximum Daily during 1935	Number of Oil and/or Gas Wells: Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Producing Gas Only	At End of 1935: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Character of Oil, Approx. Average during 1935: Gravity A.P.I. at 60° F., Weighted Average	Sulfur, Per Cent	Base[f]
57	y	y	y	y	1	0	0	0	0	1	1	1,739	1,736	0	0	0
58	y	y	y	y	4	1	0	0	3	1	4	2,452	2,438	0	0	0
59	581.5	178.8	402.7	0	5	1	0	0	3	2	5			0		
60	y	y	y	y	3	0	0	0	0	3	3	685	715			
61	0	0	0	0	6	2	0	0	2	2	4	2,455	2,440	27.7	y	y
62	y	y	y	y	9	2	0	0	2	5	7					
63	0	0	0	0	18	0	0	0	18	0	18	1,480	1,490	22.5	y	2
64	0	0	0	0	2	1	0	0	2	0	2	2,147	2,136	22.5	y	2
65	0	0	0	0	20	1	0	0	20	0	20					
66	y	y	y	y	11	9	0	0	0	11	11	2,180	2,132	0	0	0
67	0	0	0	0	8	5	0	0	8	0	8	840	832	22.5	y	2
68	0	0	0	0	1	2	0	3	0	0	3	2,460	2,453	0	0	0
69	0	0	0	0	1	0	0	1	0	0	1	1,505	1,486	0	0	0
70	7.7	0	7.7	0	218	217	0	0	210	7	217	2,680	2,705	24.5	y	2
71	0	0	0.0	0	2	2	0	0	2	0	2	1,930	1,950			
72	0	0	0	0	3	3	0	0	3	0	3	2,193	2,213	22.5	y	
73	0	0	0	0	37	37	0	0	37	0	37	2,470	2,486	22.5	y	
74	0	0	0	0	40	40	0	0	40	0	40					
75	0	0	0	0	2	2	0	0	2	0	2	2,186	2,194	22.5	y	y
76	0	0	0	0	26	26	0	0	26	0	26	2,159	2,183	22.5	y	
77	2,362.1	17,379.7	17,128.9		3,647	600	190	13	2,319	264	2,596					

Piedra de Lumbre Field.—The Piedra de Lumbre field, 1½ miles northwest of the Government Wells field, was opened in September by the completion of Magnolia Petroleum Company's No. 1 Duval County Ranch Co. with an initial production of 15 bbl. of oil per hour from the Government Wells sand at 2133 ft. One additional well was completed before the close of the year with an initial production of 90 bbl. of oil per day. One dry hole was also drilled. This field does not promise to be of major proportions but possibly will be a fair small field in this area.

Loma Alto Field.—The Loma Alto field in southern McMullen County was opened early in June by the completion of Texas Oil Company's No. 1 Atkinson, making 250 bbl. of oil per day in the Labbé (Chernosky) sand at 2195 ft. One additional well was completed as a producer but three subsequent dry holes terminated activity in this area. No drilling was done during the latter part of the year.

Lopez Field.—The Lopez field, in eastern Webb County, was opened late in June by the completion of Mills Bennett No. 1 Jesus Lopez, in survey 73, in the Mirando sand at 2126 ft. The initial production was 75 bbl. of oil through a 3/16-in. choke. Activity soon became intense and continued so during the remainder of the year.

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Character of Gas, Approx. Average during 1935: Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Porosity[i]	Producing Rock: Net Thickness, Average Ft.	Producing Rock: Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Deepest Zone Tested to End of 1935: Depth of Hole, Ft.
57	0	0	Whitsett	Eoc	Ss	Por	3	MF	15	Cockfield	3,307
58	0	0	McElroy	Eoc	Ss	Por	14	MF	13	Cockfield	3,307
59											
60											
61	*y*	0	Frio	Olig	Ss	Por	15	*x*	6	McElroy	3,610
62											
63	*y*	0	Whitsett	Eoc	Ss	Por	10	MF	6	McElroy	2,364
64	*y*	0	McElroy	Eoc	Ss	Por	10	MF	5	McElroy	2,364
65											
66	*y*	0	Queen City	Eoc	Ss	Por	55	A	0	Queen City	2,180
67	0	0	McElroy	Eoc	Ss	Por	8	*x*	1	Cockfield	2,500
68	*y*	0	McElroy	Eoc	Ss	Por	7	*x*	0	McElroy	2,460
69	*y*	0	Whitsett	Eoc	Ss	Por	19	*x*	0	McElroy	3,000
70	0	0	McElroy	Eoc	Ss	Por	7	*x*	0	McElroy	2,792
71											
72	*y*	0	McElroy	Eoc	Ss	Por	10	*x*	6	Upper Saline Bayou	4,004
73	*y*	0	McElroy	Eoc	Ss	Por	20	*x*	6	Upper Saline Bayou	4,004
74											
75	0	0	McElroy	Eoc	Ss	Por	12		3	Cockfield	2,802
76	*y*	0	McElroy	Eoc	Ss	Por	20		4	Upper Saline Bayou	3,224
77											

Carolina-Texas Field

Queen City Sand Horizon.—During the spring of 1935, the Carolina-Texas Oil & Gas Company's No. 11 Benavides, which had been abandoned on Feb. 7, 1934, was deepened to the Queen City horizon, where the sand was found from 4957 to 5056 ft., and after several tests was finally completed, making about 10 million cubic feet of gas with about three barrels of 40.5 gravity distillate with 1540 lb. rock pressure. The Queen City horizon has been producing gas in the Lopeño field of Zapata County and oil in the Roma field of Starr County, and there is a possibility that the discovery of this producing horizon in the Carolina-Texas field may stimulate some additional activity in this area.

In this series of discoveries no new producing horizons have been opened. The Labbé sand, producing in the Loma Alto and Seven Sisters fields, was discovered in the Labbé field in November, 1934. The Loma Novio sand was opened with the discovery of the Loma Novio field in December, 1934.

Wildcats

Wildcatting has been fairly active in this area during the year and, in addition to opening the fields enumerated above, has contributed a large amount of strategic information to other areas in which no production has as yet been found.

Several wildcats were drilled, however, in the western part of the area in the Claiborne group of formations, which have definitely condemned several anticlinal structures. One of these was the Humble Oil & Refining Company's No. 1 Eulalia Dominguez on the Ranchito structure, in Porcion 30 of Zapata County, which found a small amount of gas and salt water in the Queen City horizon and was carried on down to the Wilcox and abandoned at 5973 feet.

Another was O. W. Killam No. 2 Ortiz on the Pescadito structure in Webb County, about 15 miles east of Laredo. This well likewise failed to find production in the Queen City and was abandoned dry at 3635 feet.

Development and Production in West Texas for 1935

By J. D. Wheeler,* Member A.I.M.E., and H. W. Mathews†

As predicted by Messrs. Fuqua and Thompson, in last year's paper on West Texas[1], 1935 saw a marked increase in activity in this area over recent years. Both major and independent operators shared in the increased wildcatting operations, which resulted in the discovery of eight and probably nine new fields in this area. During 1935 there were 700 wells completed as compared with 468 in 1934 and only 236 in 1933. Of these completions 579 were producers with a total 24-hr. potential of over 700,000 bbl. It is estimated that the new fields discovered during 1935 added from 200,000,000 to 400,000,000 bbl. to the known oil reserve in West Texas. In addition to these new fields, many of the older producing areas scored marked extensions during the year.

New Fields

Goldsmith.—The Goldsmith field, in west central Ector County, gives promise of being the year's outstanding discovery in this area. The discovery well was completed by the Gulf Production Co. in June at a depth of 4177 ft.; it gaged 275 bbl. of 36° gravity oil in 3 hr. through 8⅝-in. casing on its first production test. The field has been extended to the east by wells drilled by Phillips and Pure on their Cowden block. Present indications are that the field may contain 10,000 productive acres, and this, together with the large flush production from only a small penetration into the pay, leads to the belief that Gulf-Goldsmith No. 1 was the outstanding Permian lime discovery of 1935. It is quite probable that production will prove to be continuous to the Landreth-Scarborough No. 1, 3¾ miles to the northwest, which was completed for a small producer late in 1934.

Sand Hills (Ordovician).—From the standpoint of creating excitement, the outstanding West Texas test of the year was no doubt Gulf-Waddell No. 1, on the northwest nose of the Sand Hills structure. This test was started late in 1934 as a deep test to the Ordovician. The Ordovician was topped above 6000 ft., considerably higher than expected. Oil shows in the Simpson were passed and the well was drilled down to the

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[1] *Trans.* A.I.M.E. (1935), **114**, 438.

Ellenberger, where sulfur water was encountered. After this water was plugged off, the hole was shot, and as the year closed a daily production of 100 bbl. was indicated by swabbing. The most productive horizon in this test appeared to be the upper Simpson, from 5980 to 6050 ft. This test has given fresh impetus to Ordovician exploratory work, which had rather started to wane with no previous discoveries other than Big Lake.

Keystone-Walton.—Another high light in the year's activity in this area was the simultaneous drilling of nine wildcat wells on the Keystone Cattle Co. block, north central Winkler County, by Gulf Production Co. This unusual activity resulted when Richardson et al. scored heavy gas production in topping the lime high in Walton No. 1 just to the northwest of the Gulf block, the leases on which were nearing their date of expiration. Of the nine wildcats, six were completed as oil producers and one, Keystone No. 1, shared honors with Richardson Walton No. 1 as the discovery well for the field. Production is from the dolomitic lime logged from 3185 to 3520 ft. in Gulf Keystone No. 1, which produced 90 bbl. of 35° gravity oil on its first 24-hr. test.

Cordova-Union.—The Cordova-Union pool was opened in the latter part of the year by Web-Ray Oil Corporation's Cordova-Union No. 1. The discovery well topped the dolomitic lime pay at 2061 ft. and was drilled to 2125 ft. Initial daily production on this well was 309 bbl., pumping, after giving the producing formation an acid treatment. This pool is in Upton County about 2½ miles southeast of the Hurdle extension of the McCamey pool. The probable extent of production has not yet been determined.

Waddell.—The Waddell pool, north central Crane County, will probably be considered as an extension to the old Waddell pool about two miles to the south, discovered by Gulf Production Co. in 1927. However, in view of the fact that the old producing area had practically been abandoned and that the producing horizon is deeper in the lime and not present in the old area, it does not seem out of line to consider this as a new discovery. Gulf-Waddell No. 9, the first large producer in the new prolific area, was completed in April at a total depth of 3543 ft. with the new deeper lime pay encountered at 3540 ft. Saturated lime, comparable to that from which wells in the original Waddell pool produced, was topped at 3370 ft. In November Magnolia Petroleum Company's Edwards No. 2 was completed for the largest natural production in West Texas, outside of Yates, when it flowed at the rate of 9726 bbl. daily, on a 4-hr. production test from dolomitic lime pay from 3535 to 3538 ft. This record was surpassed the first week in 1936 when Magnolia-Edwards No. 3, an offset to the well described above, flowed at the rate of 14,311 bbl. daily.

Foster.—The Foster pool became a new producing area in Ector County in the closing weeks of 1935, with the completion of Barnsdall-

York & Harper's Foster No. 1. While only two miles northeast of the Addis or South Cowden pool, this well is regarded as a new producing area rather than as an extension due to the steep northeast dip along the present northeast limits of the Addis pool. The discovery well recorded the first show of oil at 4090 ft. in dolomitic lime, drilled into sulfur water from 4335 to 4342 ft. and plugged back to 4310 ft. After shooting, the well flowed at the rate of 167 bbl. daily on a production test. The Foster pool is 4½ miles southeast of the Johnson pool, which was opened by Landreth Production Co. in the closing weeks of 1934 and still remains a one-well pool. Exploration between these two areas may be expected during 1936.

Garza County.—A small well was completed late in the year between two and three miles south of Post in Garza County. This well, M. L. Richards-Sullivan No. 1, pumped 32 bbl. of fluid, 22 per cent water on a 24-hr. test, with the well plugged back from 2974 ft. to 2936 ft. and treated with 2000 gal. of acid.

Schleicher County.—Schleicher County brought encouragement to the Edwards Plateau country when John M. Cooper completed his Bert Page No. 1 for a commercial gas well. This test was drilled into sulfur water at 6257 ft. and plugged back to 5540 ft. The Pennsylvanian lime section from 5399 to 5540 ft. was then given two acid treatments, one of 3000 gal. and the second of 8000 gal. Upon completion of these acid treatments, the well tested 13,800,000 cu. ft. per day of sweet gas and was spraying some oil. The gas has been piped to Eldorado, some 10 miles northwest of the well, where the operators of the well have obtained a franchise for marketing their gas.

Yoakum County.—Yoakum County shared with Schleicher County the prospect of being added to the list of West Texas counties having commercial oil or gas production. Owing to litigation over titles, the entry of Yoakum County to the ranks of the oil-producing counties has been temporarily postponed, but the prospects of C. J. Davidson & Honolulu Oil Corporation's Bennett No. 1 making a producer seem very bright. This test, which at present is bottomed at 5090 ft. had saturated lime from 5088 ft., at which depth it was several hundred feet in the Permian lime. Casing has been set and at the time the casing was run oil had risen 3800 ft. in the hole. The nearest production to this probable strike is the Hobbs field, 36 miles to the west, while the nearest production on the general trend of production for this area is the Means pool, 40 miles southeast and in northern Andrews County.

Extensions

In addition to the new fields discovered during 1935, many acres were added to the older producing areas of West Texas through extensions. Some of the more active areas together with notable extensions scored

during the year are as follows: The Means pool, Andrews County, was extended in several directions and the largest producers were completed; the McCamey pool was extended one mile northeast by Texas Pacific & Texas Company's Lane No. 1; Sun Oil Company's Holt No. 1 on the Ector-Andrews County line was completed as a producer either opening a new pool or extending the North Cowden pool 2½ miles to the northwest; the Denman pool, eastern Howard County, was extended southwest; the Grand Falls district, South Ward County, scored several extensions; the Sayre pool, at present about the most prolific area in Winkler County, was extended in all directions without defining its limits; the Scarborough-Kermit-Halley trend of sandy lime production east of the Hendrick pool in Winkler County and parallel to it was again an active area, and no dry holes have been drilled to prevent the local producing area from eventually joining; outpost drilling added several hundred acres of lime production in the northwest portion of the Yates pool; Big Lake scored a ¼-mile north extension in the Ordovician but water made an early appearance.

Drilling and Production Accomplishments

As in the past cable tool drilling has predominated in West Texas during the year. Acid treatment of wells has continued popular as well as profitable. In many instances new wells have been acid-treated before being given their original production test. Shooting with nitroglycerin was also the general practice in completing wells from the Permian lime. In addition to the shooting of new wells, there was also considerable shooting to revive production in some of the old wells. The Gulf Production Co. was particularly successful in increasing potentials in the Gulf-McElroy pool through shooting. An average increase of 300 per cent was obtained while individual wells far exceeded this. Crier-McElroy No. 9, for instance, was increased from 160 bbl. daily to 400 bbl. hourly, which at that time was the largest flowing production in West Texas outside of Yates.

Several deep tests in search of Ordovician production have been in progress during the year. Two of these, Gulf-Waddell No. 1 in Crane County and Cooper Page No. 1 in Schleicher County, were completed as producers, as previously noted. McDowell No. 1, Loffland Bros. and John T. Moore et al., in Glasscock County, made several heads of high-gravity oil from a total depth of 10,115 ft. after acid-treating the lower Pennsylvanian. The test was not a commercial producer at this depth, however, and is being deepened to the Ordovician. Skelly's University 1-D in Regan County was dry and abandoned at 9925 ft. in the Ordovician. Humble's Pollock No. 1 in northeastern Upton County was abandoned at 11,445 ft., still in the Pennsylvanian.

TABLE 1.—*Oil and Gas Production in West Texas*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935
1	Toyah, *Reeves*	16	640	0	0	640	6,500±
2	Westbrook, *Mitchell*	15	4,000	0	0	4,000	7,778,085
	Big Lake, *Regan*						
3	2,400 ft. } Permian[1]	12	*y*	*y*	*y*	*y*	2,099,313
4	3,000 ft. }	12	3,000	0	0	3,000	56,405,238
5	Ordovician	7	1,300	0	0	1,300	23,602,629
6	Emerald, *Garza*	11	320	0	0	320	41,384
7	Ira, *Scurry*	11	640	0	0	640	117,588
8	Church-Fields-McElroy, *Crane-Upton*	10	13,500	0	0	13,500	95,910,794
	Chalk-Roberts, *Howard-Glasscock*						
9	1,400-ft. pay	9	900	0	0	900	3,642,152
10	1,700-ft. pay	10	4,000	0	0	4,000	10,351,037
11	2,200-ft. pay	7	7,600	0	0	7,600	26,646,973
12	2,500-ft. pay	8	1,000	0	0	1,000	5,753,292
13	3,000-ft. pay	8	3,200	0	0	3,200	19,575,572
14	Itan-Denman, *Mitchell-Howard*	10	6,500	0	0	6,500	2,956,139
15	McCamey, *Upton-Crane*	10	6,900	0	0	6,900	28,529,667
16	Wheat, *Loving*	10	4,500	0	0	4,500	5,740,703
17	World-Powell, *Crockett*	10	2,000	0	0	2,000	4,567,959
	Yates:						
18	Lime, *Pecos-Crockett*	9	20,000±	0	0	20,000±	210,886,511
19	Sand, *Pecos*	2	700	0	0	700	134,399
20	Toborg, *Pecos*	6	1,200	0	0	1,200	3,078,714
21	Hendrick, *Winkler*		9,200	0	0	9,200	179,337,397
22	Penn, *Ector*	6	4,880	0	0	4,880	13,091,859
23	Leck, *Winkler*	8	500	0	0	500	2,983,396
24	Scarborough-Kermit-Halley, *Winkler*	8	5,160	0	0	5,160	3,125,397
25	Waddell-Henderson, *Crane*	8	6,000	0	1,000	7,000	139,884
26	Grayson, *Regan*	7	640	0	0	640	400,559
27	Pecos Valley, *Pecos*	7	1,500	0	80	1,580	443,964
28	Pryor, *Pecos*	7	160	0	0	160	26,029
	Taylor-Link, *Pecos*						
29	Lime	7	1,000	0	0	1,000	3,416,110
30	Sand	6	450	0	0	450	450,791*y*
31	Ward Co., *Ward*	7	23,000	0	1,000	24,000	16,883,529
32	Irion Co., *Irion*	6	340	0	0	340	86,542*y*
33	Masterson, *Pecos*	6	160	0	0	160	28,236
34	Deep Rock-Fuhrman, *Andrews*	5	2,420	0	0	2,420	599,671
35	Cowden, *Ector*	5	4,000	*y*	0	4,000	1,706,899
36	Sand Hills (Permian), *Crane*	5	1,000*y*	0	0	1,000*y*	48,014
37	Sand Hills (Ordovician), *Crane*	0	160	0	0	160	385
38	Todd Ranch, *Crockett*	4	360		120	480	19,274
39	Addis, *Ector*	3	1,500		40	1,540	532,006
40	Harper, *Ector*	2	320	0	0	320	64,796*y*
41	Davidson, *Ector*	1	160	0	0	160	0[2]
42	Means, *Andrews*	1	4,313	0	0	4,313	229,621
43	Scharbauer-Goldsmith, *Ector*	1	10,000±	0	0	10,000±	65,019
44	White & Baker, *Pecos*	1	320		640	960	1,855
45	Parker, *Andrews*	1	80	0	0	80	11,836
46	Landreth-Johnson, *Ector*	1	160	0	0	160	12,775
47	Sayre, *Winkler*	1	1,200	0	0	1,200	448,987
48	Keystone-Walton, *Winkler*	0	6,000	0	0	6,000	95,077
49	Cordova-Union, *Upton*	0	160	0	0	160	589
50	Foster, *Ector*	0	160	0	0	160	1,600
51	McKinzie, *Pecos*	0	160	0	0	160	2,035
52	Cooper-Page, *Schleicher*	0	0	0	160	160	0

[a] Footnotes to column heads and explanation of symbols are given on p. 215.

[1] 2,400 and 3,000-ft. pays no longer separated on production records by operating companies. All Permian production credited to 3,000-ft. pay for 1935. Big Lime and Big Lake Lime are the same zone.

[2] No pipe line connection.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.			Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935: Completed	During 1935: Abandoned
1	400	100±	0.3±	10.1	10.1	x	0	0	0	0	35	0	y
2	467,285	344,992	927	1,947	390	8.5	x	x	x	x	136	0	1
3	93,094	x	x	x	x	x	x	x	x	x	21	0	1
4	1,592,719	1,451,368	5,040	18,800	627	35	x	x	x	x	261	0	3
5	2,402,237	928,901	3,315	18,180	y	184	y	y	y	y	24	1	3
6	5,322	7,627	18	129	12.9	3.6	x	x	x	x	7	0	1
7	10,221	8,817	18	183	15	3					7	0	0
8	4,500,160	4,062,666	13,665	7,030	94	37	x	x	x	x	383	36	0
9	240,000	214,677	585	4,046		15	0	0	0	0	51	0	1
10	798,952	782,218	1,946	2,587	129y	7					266	0	0
11	3,061,535	4,341,495	13,607	3,506		66					209	29	0
12	474,672	536,305	1,578	5,753		45					41	0	0
13	893,636	900,733	2,532	6,117		34					98	0	0
14	695,278	1,162,966	4,000	594	12	33	x	x	x	x	126	58	0
15	1,553,661	2,028,050	6,588	4,135	137	21	x	x	x	x	349	43	y
16	802,144	658,977	1,813	1,276	183	24.2	x	x	x	x	88	4	1
17	237,273	325,259	848	2,280	175	23	x	x	x	x	56	1	0
18	15,409,209	15,197,819	39,500	10,550±	105±	82	108,614	4,741	3,202	17	473	17	0
19	54,559	75,585	277	192	13	40	x	x	x	x	7	3	0
20	422,504	644,519	1,890	2,566	128	16	x	x	x	x	119	29	0
21	6,356,359	5,700,186	14,447	19,500	x	63y	x	x	x	x	625	0	y
22	2,017,697	2,051,447	5,157	2,683	67	41	12,937	2,823	2,190y	6	129	32	1
23	196,273	223,401	576	5,967	x	52	x	x	x	x	16	0	0
24	839,968	935,821	3,072	6,056	151	31	x	x	x	x	98	8	0
25	1,736	99,016	525	23	1.5	75	y	y	y	y	14	7	0
26	65,258	67,770	172	625	x	29	x	x	x	x	5	0	0
27	43,742	73,599	382	296	20	10.6	x	x	y	y	41	4	0
28	1,490	3,524	10	163	33	5	x	x	x	x	3	0	0
29	361,644	420,273	1,190	3,416	228		x	x	x	x	48	3	1
30	18,270	15,000y	42	1,002	167		x	x	x	x	8		
31	3,551,902	6,195,408	19,346	733	14	38	x	x	x	x	521	168	0
32	10,096	16,000y	45y	243y	24y	5	x	x	x	x	16	2	1
33	10,916	7,040	19.6	179.5	35.9	3.9	x	x	x	x	7	1	0
34	175,097	410,578	1,262	248	10y	97	244y	2y	242y	1.5y	13	3	0
35	155,333	1,158,316	3,881	425	14	75y	x	x	x	x	y	23	0
36	10,691	10,361	67	48y	2.5y	22	x	x	x	x	3	2	0
37	0	385	0			0	x	0	x	x	1	1	0
38	10,718	8,556	2	53.5	5.3	2	x	x	x	x	6	0	4
39	190,034	224,128	614	354	35	41	x	x	x	x	15	2	0
40	24,796	40,000y	110			55	x	x	x	x	2	1	0
41	0	0	0			0	x	x	x	x	1	0	0
42	22,522	207,099	625	48	4	96.3	458	149	309	2	13	10	0
43	0	65,019	321			80	x	x	x	x	6	5	0
44	91	1,764	5	6	0.6	5	0	0	0	0	3	2	0
45	1,500	10,336	29	129	26y	15	x	x	x	x	2	1	0
46	0	12,775	35	80	2.7	35	x	x	x	x	1	0	0
47	4,378	444,609	3,023	374	18y	60.4	x	x	x	x	50	48	0
48	0	95,077	580	15.8	0.5y	58y	x	0	x	x	11	11	0
49	0	589	0			0	x	x	x	x	1	1	0
50	0	1,600	0	10	y	0	x	x	x	x	1	1	0
51	0	2,035	0	12.5	y	0	x	x	x	x	2	2	0
52	0	0	0	0	0	0	y	0	y	y	1	1	0

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells: At End of 1935: Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	To Top of Productive Zone	Oil Production Methods at End of 1934: Number of Wells: Flowing	Pumping	Gas-lift	Air-lift	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of: 1934	1935	Character of Oil, Approx. Average during 1934: Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	*y*	10±	0	0	10±	100	100	0	10±	0	0	*x*	0	0			27	1.7	M
2	16	109	0	0	109	3,000	2,800	0	109	0	0	1,000	*y*	*y*	27	25	26	2.5	MA
3	0	*y*	0	0	*y*	2,500	2,375	0		0	0	*x*	*x*	*x*			35	*y*	M
4	4	144	0	0	144	3,000	2,970	0	144	0	0	*x*	*x*	*x*			36	0.4	M
5	3	18		0	18	8,700	8,300	13	0	5	0	3,750	*y*	2,000±	58	42	46	0.2	P
6	0	5	0	0	5	2,600	2,510	0	5	0	0	*x*	*x*	*x*	40	38	39	*y*	*y*
7	0	5	0	0	5	2,395	2,325	0	5	0	0	*x*	*x*	*x*	25	25	25	2.06	M
8	*y*	377	0	0	377	3,000	2,800	65	311	1	0	725	*y*	*y*	33	30	32	2.5	M
9	0	50	0	0	50	1,400	1,280	0	50	0	0	*x*	*x*	*x*			33	1.0	*y*
10	0	264			264	1,750	1,650	0	264	0	0	*x*	*x*	*x*			32	0.8	*y*
11	0	209	0	0	209	2,300	2,150	0	209	0	0	*x*	*x*	*x*			30	1.6	*y*
12	0	41	0	0	41	2,600	2,500	0	41	0	0	*x*	*x*	*x*			27	3.4	*y*
13	0	76	0	0	76	3,000	2,900	0	76	0	0	*x*	*x*	*x*			27	2.0	*y*
14	1	125	0	0	125	2,800	2,450	5	120	0	0	*x*	*x*	500±	34	30	32	2.0	M
15	30	319	0	0	319	2,600	2,000	6	313	0	0	*x*	*x*	*x*	*y*	*y*	28	2.0	M
16	7	75	0	0	75	4,304	4,297	71	4	0	0	1,650	1,300	1,250	39	37	38	0.2	P, M
17	0	37	0	0	37	2,550	2,450	0	37	0	0	*x*	*x*	*x*	30	28	29	0.7	MA
18	0	473	0	0	473	1,450	1,310	446	23	4	0	700*y*	533	532	31	29	30	1.6	M
19	0	7	0	0	7	1,100	900	0	7	0	0				*y*	*y*	32	*y*	
20	0	118	0	0	118	445	400	0	118	0	0	*x*	*x*	*x*	*y*	*y*	23	1.9	M
21	54*y*	226	0	*y*	*y*	2,900	2,600	*y*	*y*	2	0	1,600±	*x*	*x*	35	24	28	1.5	M
22	4	124*y*	*y*	0	124	3,700	3,590	95	28	1	0	1,000*y*	975*y*	946*y*	35	32	33	2.6	M
23	1	11	0	0	11	3,100	3,000	0	11	0	0	1,600+	*y*	*y*	*y*	*y*	28	1.5	M
24	0	98	0	0	98	3,300	2,800	89	9	0	0	1,400	*y*	*y*	38	34	36	1.2	P, M
25	3	7	0	2	11	3,540	3,200	8	1	0	0	1,500+	*y*	*y*	34	30	32	1.5	M
26	0	5	0	0	5	3,100	3,050	0	5	0	0	*x*	*x*	*x*	33	31	32	1.0	M
27	*y*	32	0	2	34	1,600	1,300	24	8	0	0	*x*	*x*	250±	37	23	31	1.0	PA
28	0	2	0	0	2	1,400	1,385	0	2	0	0	*x*	*x*	*x*	24	24	24	0.6	A
29	0	47	0	0	47	1,675	1,630	0	47	0	0	*x*	*x*	*x*	31	29	30	1.3	M
30	0	8	0	0	8	1,000	970	0	8	0	0	*x*	*x*	*x*	28	28	28	*y*	
31	8	507	*y*	6	513	2,700	2,400	*y*	*y*	*y*	*y*	1,400±	1,100±	1,000±	38	31	36	1.2	P, M
32	0	9	0	0	9	1,410	1,400	0	9	0	0	*x*	*x*	*x*	*y*	*y*	40	*y*	*y*
33	3	5	0	0	5	1,400	1,200	0	5	0	0	*x*	*x*	*x*	*y*	*y*	28	*y*	M
34	0	13	0	0	13	4,628	4,348	7	6	0	0	*x*	*y*	*y*	*y*	*y*	29.1	*y*	M
35	0	54		0	54	4,300	4,200	45*y*	9*y*	0	0	1,640	1,575	*y*	34	30	32	1.7	M
36	0	2	1	0	3	4,300	3,000	2	1	0	0	*x*	*x*	*x*	37	30	34	0.7	M
37	0	1	0	0	1	6,450	5,980	0	1	0	0	*x*	*x*	*x*	35	35	35	0	M
38	1	1	0	0	1	2,600	1,200	0	1	0	0	*x*	*x*	*x*	*y*	*y*	*y*	*y*	M
39	0	15	0	0	15	4,100	3,900	12	3	0	0	1,485	1,200	*y*	34	30	32	*y*	*y*
40	0	2	0	0	2	4,338	4,147	0	2	0	0	*x*	*x*	*x*			37	*y*	*y*
41	1	0	0	0	0	4,500	4,300					*x*	*x*	*y*	29	29	29	*y*	M
42	0	12	0	1	13	4,539	4,468	10	0	3	0	1,600	*y*	*y*	*y*	*y*	31	*y*	M
43	1	5	0	0	5	4,200	4,100	5	0	0	0	2,000+	*y*	2,000+	39	37	38	1.3	M
44	2	1	0	0	1	1,700	1,650	0	1	0	0	*x*	*x*	*x*	31	31	31	*y*	M
45	1	1	0	0	1	4,790	4,627	0	1	0	0	*x*	*x*	*x*	*y*	*y*	30*y*	*y*	M
46	0	1	0	0	1	4,166	4,100	0	1	0	0	*x*	*x*	500±	36.2	35.8	36.0	2.0	M
47	0	49	0	1	50	3,000	2,780	50	0	0	0	1,100	1,100	1,100	37	35	36	*y*	M
48	0	11		0	11	3,600	3,000	11	0	0	0	2,000+		2,000+	38	36	37	1.5±	M
49	0	1	0	0	1	2,125	2,060	0	1	0	0	*x*		*x*	*y*	*y*	*y*	*y*	M
50	0	1	0	0	1	4,310	*y*	1	0	0	0	*x*	0	*x*	*y*	*y*	*y*	*y*	M
51	0	2	0	0	2	1,378	1,338	2	0	0	0	*x*		*x*	*y*	*y*	26	*y*	P
52	1	0	0	0	0	5,540	5,400	0	0	0	0	*y*	0	*y*					

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Character of Gas, Approx. Average during 1935: Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Porosity	Producing Rock: Net Thickness, Average Ft.	Producing Rock: Structure	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Deepest Zone Tested to End of 1935: Depth of Hole in Feet	Reference to Text[k]
1	*x*	*x*		Pli?	Sh	Por	1	MC	*y*	Delaware Mt.	4,133	
2			Big lime	Per	DL	Por	50	MC	3	Pen	5,250	
3	*y*	*y*		Per	S	20	*x*	AD		L Ord	9,562	
4	*y*	4.0	Big Lake lime	Per	DL	Por Cav	30	AD	0	L Ord	9,562	
5	1,200	0.9	Ellenberger	Ord	L	Por		D	1	L Ord	9,562	
6			Big lime	Per	SLS	Por	10	A	1	Per	4,801	
7			Big lime	Per	DL	Por	25	A	7	Per	4,528	
8	1,100	1.7	Big Lake lime	Per	DL	15	75	A	3	Ord	12,786	Discussed.
9			1,400-ft. Yates sand	Per	S	Por	*x*	A	3	Ord	10,906	
10			1,700-ft. pay	Per	S	22	20	A	3	Ord	10,906	
11			2,200-ft. pay	Per	L	Por	*x*	A	9	Ord	10,906	
12			2,500-ft. pay	Per	L	Por	*x*	A	1	Ord	10,906	
13			3,000-ft. pay	Per	DL	Por	*x*	A	9	Ord	10,906	
14			Big lime	Per	DL	Por	50	A	10	Per	4,220	
15	*x*	*x*	Big Lake lime	Per	DL	Cav Por	30	A	40*y*	Per	4,610	
16	1,000	1.0	Delaware	Per	Sand	Por	7	M Slight Nose	5	Delaware sand	5,083	
17			Big lime	Per	DL	Por	13	AD	4	Ord	8,830	
18	*y*	1.0	Yates sand	Per	DL	Por Cav	100±	A	15	Per	1,938	Discussed.
19	*x*	*x*	Yates sand	Per	S	Por	15	AL	0	Per	1,852	
20	*x*	*x*	Toborg sand	Cret	SD	Por	20	AL	19	Per	1,400±	
21	*y*	*y*	Big lime	Per	D	Por Cav	*x*	A	26	Per	3,962	
22	*y*	1.5	Big lime	Per	DL	Por	40	A	3	Per	4,002	
23	*x*	*x*	Big lime	Per	DL	Por Cav	*x*	A	5	Per	3,780	
24	1,100	1.0	Scarborough and O'Brien sand	Per	SS LLS	Por	40	AM	6	Per	4,639	Discussed.
25	*x*	*x*	Big Lake lime	Per	DL	Por	15	A	2	Per	3,859	
26	*x*	*x*	Big lime	Per	DL	Por	*x*	D	1	Miss	9,967	
27	1,000	*y*	Pecos Valley sand	Per	S	Por	15	A	10	Per	2,550	
28	*x*	*x*		Per	SH	Por	5	A	6	Per	4,375	
29	*x*	*x*	Big lime	Per	DL	Por	15	D	0	Per	2,185	
30	*x*	*x*	Yates sand	Per	S	Por	6	D	1	Per	2,185	
31	1,129	1.2	O'Brien sand	Per	SD	Por	50	ML	22	Per	4,825	
32	*y*	*y*		Per	S	Por	10	M	17	Per	3,511	
33	*y*	*y*	Pecos Valley sand	Per	S	Por	5	M	5	Per	1,675	
34	*y*	*y*	Big lime	Per	D	Por	25*y*	A	3	Per	5,088	
35	*y*	0.5	Big lime	Per	DS	19.1	30	A	0	Per	4,627	
36	*x*	*x*	Big Lake lime Tubb pay	Per	D	Por	20	AD	2	Ord	6,450	
37	*x*	*x*	Simpson Ordovician	Ord	LS	Por	100	AD	0	Ord	6,450	Discussed.
38	*x*	*x*	Big lime	Per	D	Por	10	A	0	Ord	8,041	
39	*y*	0.5	Big lime	Per	DS	16.5	10	DA	3	Per	4,702	
40	*y*	*y*	Big Lake lime	Per	DS	Por	10	A	0	Per	4,338	
41	*y*	*y*	Big Lake lime	Per	DL	Por	30	A	0	Per	4,509	
42	603	*y*	Big lime	Per	DL	17	12	A	0	Per	4,556	
43	*x*	*x*	Big Lake lime	Per	DL	Por	25	A	2	Per	4,557	
44	*x*	*x*	Big lime	Per	DL	Por	10	A	8	Ord	9,811	
45	*y*	*y*	Big lime	Per	DL	Por	5*y*	N	0	Per	4,804	
46	*x*	*x*	Big lime	Per	DS	Por	30	A	0	Per	4,180	
47	*x*	*x*	Scarborough sand, Big lime	Per	SS LS DL	Por	8–35	AM	0	Per	3,020	
48	*y*	*y*	Big lime	Per	LS	Por	30±	AD	3	Per	4,463	Discussed.
49	*y*	*y*	Big lime	Per	DL	Por	*y*	A	0	Per	2,125	Discussed.
50	*x*	*x*	Big lime	Per	DL	Por	*y*	A	0	Per	4,310	Discussed.
51	*x*	*x*	Sandy lime	Per		Por				Per		
52	*y*	*y*	*y*	Pen	LS	Por	*y*	A	0	Pen	6,257	Discussed.

Perhaps the outstanding drilling achievement of the year was accomplished by Gulf Production Co. in drilling McElroy No. 103 to a record depth of 12,786 ft. The formation between 10,000 and 11,000 ft. was extremely hard chert and the entire year of 1934 was spent in drilling from 8600 to 11,000 ft. Several good shows were obtained in the Ordovician but commercial production was not developed and the well was plugged back to the Permian lime producing horizon. Very complete records were kept on this test on replacements, boiler maintenance, bit performance, drilling mud, etc., which should prove useful to the operators in their future deep tests.

In the South Ward field the California Company has developed a completion program that is very satisfactory in completing wells from the formations of rather low pressures but high porosity. The present practice is to set the 7-in. casing at approximately 2350 ft., which is through the dry gas zone. In drilling in, a 7-in. master gate is installed on the casing with a 7-in. four-way tee and a Sheldon & Burden drilling-through packer above the master gate, a 3-in. flush joint drill pipe being used. After the cement is drilled out, the drilling water is blown from the hole with high-pressure gas. This is repeated several times, which gives a check on the water shutoff. From this point oil is used for circulating. The well is drilled to the desired depth, flowing continuously either to the pump sump or through a separator into stock tanks, the return oil being lightened by the injection of gas. Upon the completion of drilling, the drill pipe is withdrawn and the well shot with nitroglycerin. The drill pipe is then rotated to bottom circulating oil. With the pipe on bottom the pumps are shut down and the fluid blown from the hole by injecting gas under 800 lb. per square inch pressure through the drill pipe. As soon as the hole has been blown dry the valve on the input line is closed and the well allowed to stand for an hour or two. With the well blown dry, a large pressure differential is created between the well bore and the producing formation, which results in the formation fluid rapidly coming into the well bore, bringing the shot debris with it. The well is then again blown dry and the operation repeated if necessary, the hole being clean in 24 hr. The saving in time obtained by this method of cleaning out is two weeks or more to the well, and the possibility of "mudding up" the face of the sand, as might be done in using cable tools, is eliminated.

The Yates pool continues to be the outstanding field in West Texas. The second largest well in the history of the field was completed during the year when the California Company's Bob Reid No. 3 produced 7005 bbl. on a one-hour potential test, or at the rate of 168,120 bbl. daily. During the year 15,272,404 bbl. of crude was produced in the Yates pool (Tobarg sand production not included) with a very slight drop in reservoir

pressure, as a result of a successful gas-conservation program put into effect by the operating companies a few years ago.

Outlook for 1936

Activity in West Texas, which has been steadily increasing since 1933, promises to continue during 1936 at an even accelerated rate. The rise in crude prices that came at the end of 1935, together with the ability of operators to dispose of all oil produced in accordance with the State's proration orders, will lead to the drilling of many wildcats and semiwildcats in 1936. As many leases are expiring within the next two years, a number of deep tests are expected in the Edwards Plateau region. The string of sandy lime fields in eastern Winkler County will continue to be a very active area. The prospective discovery in Yoakum County will lead to considerable wildcatting in Gains County, lying between this strike and the Means pool in northern Andrews County. In addition to the wildcatting, the increase in the price of crude, together with the more optimistic feeling within the industry, will lead to much reconditioning work, which has been neglected during the lean years.

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Oil and Gas Development in Utah, 1935*

By E. W. Henderson†

(New York Meeting, February, 1936)

Development work in the state of Utah in 1935 consisted of additional work done on wildcat tests started in previous years and on a number of new wildcat tests started during the year. No effort was made to extend areas or to discover deeper productive horizons in proven fields. Principal areas of development were in Daggett County, northeastern Utah; Grand and Emery counties, east-central Utah; and in Washington County, southwestern Utah.

Daggett County

Clay Basin.—The Mountain Fuel Supply Co. deepened Murphy No. 2, sec. 21, T.3N., R.24E., from 6030 to 6790 ft. for a test of the Sundance formation. Two sandstone members at 6520 to 6644 ft. and 6737 to 6790 ft. contained water. The hole was plugged back to 5860 ft. and left as a future gas supply for the Salt Lake City-Ogden pipe line. The failure of the Sundance formation to produce in this test, in view of the recent Sundance discoveries in Colorado and Wyoming, was disappointing.

Emery County

Last Chance.—The wildcat test of the Ramsey Petroleum Corporation, Well No. 1-X, sec. 18, T.26S., R.7E., completed plugging back from total depth of 3168 ft. to 2771 ft. and was shut in as a gas well. A gas sand at 2724 to 2771 ft. produced approximately 21 million cubic feet. A deep test of the structure will be started upon approval of a unit plan of development.

Grand County

Cisco.—The wildcat test of the Utah Southern Oil Co., sec. 33, T.22S., R.22E., of which the total depth was 1720 ft. on Dec. 31, 1935, is the most interesting operation in the state. Location of the test was deter-

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† U.S. Geological Survey, Salt Lake City, Utah.

mined by means of a seismograph survey of the area that indicated beds of Pennsylvanian age at a depth of approximately 2500 ft., feathered out against an old granitic mass forming the rim of a depositional basin. It is believed that the Pennsylvanian formation at such a position will contain thick, continuous beds of sand—a feature lacking in other tests drilled in southeastern Utah and a possible explanation of why such tests found oil in noncommercial quantities. The unit plan of development and operating agreement, providing for a flat royalty percentage of all production to be paid landowners, perfected by the company for testing its holdings in the area, is considered an outstanding example of what can be accomplished under unit plans.

Green River.—A second test of the Green River structure, Glen Ruby et al., sec. 34, T.21S., R.16E., of which the total depth was 100 ft. on Dec. 31, 1935, starts in Jurassic formation and will test beds of Triassic, Permian and Pennsylvanian age.

Seven Mile.—The Columbia Crude Corporation test in sec. 12, T.25S., R.20E., total depth 135 ft. Dec. 31, 1935, starts in the Rico formation of Permian age and will test the Paradox formation of early Pennsylvanian age expected at a depth of approximately 2500 feet.

Washington County

Bloomington Dome.—Test of Escalante Explorations, Inc., sec. 19, T.43S., R.15W., was drilled to 4114 ft., where a showing of oil in beds of Pennsylvanian age was reported. A premature explosion while shooting this well on March 6, 1935, resulted in the death of 10 persons and the destruction of all surface equipment. No further effort was made to deepen the well subsequent to the explosion.

Harrisburg Dome.—Efforts during the year to shut off water in the Virgin Dome Oil Co. well, sec. 16, T.42S., R.14W., were not successful and operations were suspended indefinitely at approximately 3000 feet.

Punchbowl.—Arrowhead Petroleum Corporation test in sec. 1, T.43S., R.15W., reached a total depth of 2350 ft. in December, 1935, and was drilling ahead in a massive sandstone correlated as Supai of uncertain Permian or Pennsylvanian age.

Producing Fields

Carbon County.—At Farnham field, T.15S., R.11E., the Carbon Dioxice & Chemical Co. completed a 5-mile pipe line, combination 4 and 8 in., to transport carbon dioxide gas to a plant at Wellington, Utah, and a plant, estimated capacity 10 tons ice and 15 tons liquid each 24 hr., for processing the gas. Estimated cost of plant and pipe line, $75,000.

Grand County.—At Cisco dome, T.20S., R.20E., the carbon-black plant was dismantled during the year. The operator will probably plug all wells and completely abandon the field during 1936.

San Juan County.—All operations in the San Juan field, T.41S., R.19E., remained suspended in 1935.

Uintah County.—At Ashley Valley, T.5S., R.22E., repair work done on the gas wells during 1935 resulted in decrease of water pressure on the producing sand and increase of gas pressure. Other field operations were of routine nature.

TABLE 1.—*Oil and Gas Production in Utah in* 1935

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Gas	Total	Total Oil Production, Bbl.: To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935	Average Oil Production, Bbl.: Per Acre to End of 1935[b]	Per Acre-Foot to End of 1935	Per Well Daily during Nov., 1935
1	Virgin, *Washington*	28	450	0	450	154,*xxx*	3,500	4,*xxx*	12	343	172	1
2	San Juan, *San Juan*	26	160	0	160	11,*xxx*	1*xx*	50	0.2	*x*	*x*	*x*
3	Farnham, *Carbon*	12[1]	0	600	600	0	0	0	0	0	0	0
4	Cisco, *Grand*	11[2]	0	2,000	2,000	0	0	0	0	0	0	0
5	Ashley Valley, *Uintah*	10[3]	0	240	240	0	0	0	0	0	0	0
6	Total		610	2,840	3,450	165,*xxx*	3,6*xx*	4,*xxx*	12.2			

[b] Footnotes to column heads and explanation of symbols are given on page 215.
[1] Discovered April, 1923; began producing April, 1931.
[2] Discovered September, 1924; began producing February, 1927.
[3] Discovered April, 1925; began producing September, 1929.

Line Number	Total Gas Production, Millions Cu. Ft.: To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Number of Oil and/or Gas Wells: Completed to End of 1935	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Pumping	Misc.
1	0	0	0	0	50	0	21	11	0	11	665[6]	665[6]	10	1[7]
2	0	0	0	0	9	8	1	0	0	0	200	194	1	0
3	643.8[4]	38.4	22.5	0.2	2	0	0	0	1	1	3,114	3,093	0	0
4	3,128	0[5]	0	0	10	0	10	0	10	10	2,174	2,056	0	0
5	29.23	36.4	45.7	0.2	2	0	0	0	2	2	1,675	1,665	0	0
6	4,064.1	74.8	68.2	0.4	73	8	32	11	13	24				

[4] Includes 500 million cu. ft. estimated to have been wasted while drilling discovery well.
[5] Shut in since February, 1931.
[6] 515 to 815 ft., depending on position of well on monoclinal structure.
[7] Pumping with vacuum.

Washington County.—Operations in the Virgin field, T.41S., R.12W., consisted in repairing and producing wells and drilling two dry holes within the proven area.

Acknowledgments

The writer gratefully acknowledges the information received from and assistance given by the following named: H. W. C. Prommel, Consulting

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935					Character of Gas, Approx. Average during 1935		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935	
	Initial	Average at End of 1934	Average at End of 1935	Gravity A.P.I. at 60° F. Maximum	Gravity A.P.I. at 60° F. Minimum	Gravity A.P.I. at 60° F. Weighted Average	Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1	0	0	0	38	24	34	1.00–2.50	P			Kaibab-Moenkopi Cont. or Upper Kaibab	Tri or Per	L	Por	2	MC	72	Per Coconino-Supai	2,195
2	0	0	0	40	39	39	0.24	M			Goodridge	Pen	S	Por	6	S	116[8]	Pen Hermosa	3,633
3	750	620	620						CO_2		Moenkopi-Kaibab	Tri-Per	S	Por	21	AF	1	Per Kaibab	3,235
4	750	325	325						1,080	0.0	Dakota-Morrison	CreL	S	Por	15	D	3	Jur Kayenta	3,045
5	580	270	230						980	0.0	Morrison	CreL	S	Por	10	AF	3	Jur Nugget	2,720
6																			

[8] Includes assessment holes.

TABLE 2.—*Summary of Drilling Operations in Utah in* 1935

Important Wildcats Drilled in 1935

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Pressure, per Sq. In., Casing	Remarks
		Section	Township, Lat.	Range, Long.					Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		
1	Daggett...											
2	Daggett...	21	3 N.	24 E.	6790	Cre-Mancos	Jur-Sundance	Mountain Fuel Supply Co.	0	32.0	2270	PB. 5860 ft. Gas production from Cre-Dakota and Lakota.
3	Emery.....	18	26 S.	7 E.	3168	Jur-Carmel	Per-Coconino	Ramsey Petroleum Corp.	0	21.0	410	PB. 2771 ft. Gas production from Tri-Moenkopi.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	1	5
Number of oil wells completed during 1935	0	0
Number of gas wells completed during 1935	0	2
Number of dry holes completed during 1935	2	0

Geologist and Mining Engineer, Denver, Colo.; H. B. Soyster, Chief, Oil and Gas Leasing Division, U.S. Geological Survey, Washington, D.C.; G. T. Hansen, President, Utah Southern Oil Co., Salt Lake City, Utah; C. E. Dobbin, Geologist, U.S. Geological Survey, Denver, Colo. Permission to publish production data was given by J. R. Douglas, Manager, Uintah Gas Co., Vernal, Utah and A. E. Goodwin, President, Carbon Dioxice & Chemical Co., Seattle, Washington.

Oil and Gas Development in West Virginia during 1935

By David B. Reger,* Member A.I.M.E.

(New York Meeting, February, 1936)

The year 1935 was mostly quiet in West Virginia, and devoted to routine drilling in old pools and extensions. A notable exception to this general rule, however, was the further development and proving of a field of gas discovered in 1930 in the deep Oriskany sand (L. Dev.) in Kanawha County, as later discussed. No new pools of oil were found and little or no attempt was made to search for them. No new pools of gas were recorded but various extensions of old pools were made. There were no new pipe line extensions of consequence, either for oil or gas. Operating technology was much the same as in recent years, there having been some further advances in repressuring oil wells and in the use of acid for treating small wells in calcareous formations, and some change in the technique of shooting gas wells. Financially, there has been a full market for all crude oil produced and a fair market for gas. There have been occasional transfers of producing oil or gas properties, mainly between established companies. Most of the attempts made to finance mergers and new developments have failed largely because of difficulties encountered under the Federal securities act. This situation has prevented the normal turnover of properties by small operators who frequently desire to sell partly developed interests and then step out into new ventures.

New Development

In 1935 the State issued 569 permits for drilling and records the same number of completions. One trade journal records 533 completions and another 483. A running record kept by the writer accounts for 713 completions, with 156 oil wells, 417 gas wells and 140 dry holes (Table 3). Some of these completions may be old wells drilled to deeper sands. Some, apparently, have been drilled without legal permit.

Extensions of Producing Areas

Ritchie County has again led all others in new drilling, with 137 completions as compared to 74 in Calhoun and 61 in Cabell. This Ritchie County drilling was done mainly to extend or further develop old pools

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of oil and gas. The county is highly favored by small operators because a well not more than 2500 ft. deep will reach most of the producing sands.

In Proctor district, Wetzel County, five gas-well completions were reported in the Maxton (Mis.), Big Injun (Mis.) and Gordon (U. Dev.) sands, with average open flow of 855,000 cu. ft. and 600 lb. rock pressure per well, along or near the New Martinsville anticline. These wells indicate renewed activity in a locality where the prospect had been somewhat discouraging.

In Warren district, Upshur County, a new Benson sand (U. Dev.) gas well (Bennett, 1) represents a 5-mile southeastward advance of production in this sand. In Meade district, Upshur County, also, a similar Benson well (Talbott, 1) is 4 miles southeast of former Benson production. If the Benson territory should similarly advance along the 15-mile front that separates these two wildcats the county may have 60 sq. miles or more of new gas.

In Gilmer County the new oil excitement of 1934 has practically vanished with no great increase of production, there being only five new

TABLE 1.—*Oil and Gas Territory, Reserves, Production, and Wells in West Virginia as of Dec.* 31, 1935

OIL AND GAS TERRITORY AND RESERVES

Held by Lease, Acres	Probable Territory not Held by Lease, Acres	Proved and Probable, Acres		Reserves	
		Oil	Gas	Oil, Bbl.	Gas, Millions Cu. Ft.
4,000,000	1,000,000	750,000	2,500,000	100,000,000	7,000,000

OIL AND GAS PRODUCTION

	Oil, Bbl.	Average Oil per Well Daily, Bbl.	Gas, Millions Cu. Ft.	Average Gas per Well Daily, Cu. Ft.
To end of 1935	395,265,000		5,881,705	
During 1934	4,096,000		95,000	
During 1935	3,908,000	0.57	105,000 ±	23,544

NUMBER OF OIL AND/OR GAS WELLS

Completed to End of 1935, Oil and Gas	Completed during 1935		At End of 1935	
	Oil	Gas	Oil	Gas
60,500 ±	157	417	18,700 ±	12,800 ±

oil wells in 1935, with total of 25 bbl. Gas development, however, continued to be fairly active.

In Union district, Wood County, further drilling of the year indicates a westward extension of the Salt sand (basal Pen.) territory in the direction of Doyle.

In Calhoun County, only nine oil wells were drilled, but the county had 52 new gas wells with fair average production.

In Cabell County the Big Injun sand (L. Mis.) gas development on Guyandot River near Saltrock, McComas district, has continued to be active. At present there are about 40 wells, as compared to less than 20 one year ago; and 8 or 10 new wells are drilling. The initial flow of wells in 1935 has ranged from 1,500,000 to 5,000,000 cu. feet.

In Slab Fork district, Raleigh County, three additional gas wells have been drilled on Slab Fork northeast of Slab Fork village, making a total of five wells in this development. Production is mainly in the Big Lime (Greenbrier, Mis.) at depths of 2500 to 2800 ft. Initial production after acid treatment, which has proved beneficial, has varied from 50,000 to 900,000 cu. ft., with rock pressures of 550 to 650 lb. One wildcat, drilled 3 miles southeast of production in 1935, resulted in a dry hole. Another well is now drilling in a defined location. This development, small in itself, assumes importance because of its location in the heart of the low-volatile coal area of the state where carbon ratios are very high.

In Kanawha County the event of the year has been the development of large gas wells in the Oriskany sand (L. Dev.). Before 1935 eight wells had been completed to this sand in the county, resulting in one oil well and five small gas wells. The finding of one oil well of 158 bbl. late in 1934 started drilling over a wide area, with the result that 1935 saw the completion of 16 wells through the Oriskany, with 10 gas wells and 6 dry holes, but without further development of oil, as only one well had a 10-bbl. show. In January, 1936, two additional gas wells were completed and 16 wells were drilling. To this date the results of the field show 26 completed wells, with one oil well, 17 gas wells and 8 dry holes. Total initial daily gas-well capacity has been 33,164,000 cu. ft., making an average of 1,950,000 cu. ft. per well. Rock pressures vary from 1200 to 1900 lb. (Table 4).

The available records of 12 wells, either productive or dry, that have gone through the sand in this county show an Oriskany sand thickness of 23 ft. Generally, the sand is hard and close, and entirely free from salt water. Some of the smaller wells have increased to more than 10 times the natural flow when shot with glycerin.

The field lies partly along the northwestern flank of the Warfield (Chestnut Ridge) anticline, which passes northeastward across the state from Warfield, Ky., to the Pennsylvania line near Morgantown, W. Va., but which is only a slight fold in Kanawha County; and partly on the

axis of the Milliken anticline, which is a minor fold branching from the Warfield in Kanawha County and passing northward into Roane County. Available subsurface profiles show a dome of moderate height but of considerable areal extent near the intersection of these two anticlines and possibly coincident with the gas field, although the drilling to date has by no means defined the field or proved all of the interior area. At present about 4000 acres on the Milliken anticline and about 3000 acres on the Warfield anticline are fairly well proved. Considering the structure and the outpost wells, exploration would appear to be justified in a total area of about 50,000 acres. Any present estimate of ultimate production per acre or per well would be entirely futile.

In addition to the production obtained in the Oriskany sand, various wells in the field have found good production in the Genesee and other shales (Childres sand—Mid. Dev.) and have been stopped to produce this gas without further attempt to reach the Oriskany. The occurrence of such gas in this locality is sporadic but very welcome when found. A considerable part of the field, also, has previously produced gas from the Big Lime (Mis.) and other comparatively shallow formations.

The apparent success of deep sand drilling to the Oriskany sand (L. Dev.) by the gas operators of Kanawha County, the widespread development of shale gas in the Middle Devonian, and the known presence of gas in the still deeper Newburg sand (Sil.) farther southwest in the state, compel the writer to recall an early discussion of this matter before the Institute[1] in which such drilling was suggested and advocated.

TABLE 2.—*Important Wildcats Drilled in* 1935, *West Virginia*

	County	Location			Total Depth, Ft.	Surface Formation
		Magisterial District	Lat.	Long.		
1	Kanawha	Cabin Creek	N. 38° 14′ 9″	W. 81° 16′ 50″	6265	Pen-Kanawha
2	Kanawha	Elk	N. 38° 27′ 30″	W. 81° 32′ 10″	4852	Pen-Conemaugh
3	Kanawha	Elk	N. 38° 24′ 10″	W. 81° 31′ 25″	4857	Pen-Allegheny
4	Kanawha	Jefferson	N. 38° 19′ 47″	W. 81° 44′ 40″	6285	Pen-Conemaugh
5	Kanawha	Loudon	N. 38° 20′ 5″	W. 81° 39′ 40″	4971	Pen-Conemaugh
6	Kanawha	Malden	N. 38° 17′ 55″	W. 81° 32′ 5″	4828	Pen-Kanawha
7	Kanawha	Union	N. 38° 22′ 45″	W. 81° 39′ 48″	4900	Pen-Conemaugh
8	Raleigh	Slab Fork	N. 37° 39, 38″	W. 81° 17′ 20″	3603	Pen-New River
9	Upshur	Warren	N. 39° 3′ 50″	W. 80° 14′ 50″		Pen-Conemaugh
10	Upshur	Meade	N. 38° 51′ 10″	W. 80° 16′ 50″	3700	Pen-Conemaugh

[1] D. B. Reger: The Possibility of Deep Sand Oil and Gas in the Appalachian Geosyncline of West Virginia. *Trans.* A.I.M.E. (1917) **66**, 856–875.

Deep sand exploration at present is mainly confined to Kanawha County but an Oriskany test is nearing completion on the Arches Fork anticline in West Union district, Doddridge County. A similar well near completion on the Chestnut Ridge anticline in South Union Township, Fayette County, Pa., is only 10 miles north of the West Virginia line; and its result will be a guide to exploration of the same structure in Monongalia County.

Operating and Exploring Technology

The use of hydrochloric acid for treating limestone wells that show small quantities of oil or gas continues to be used with considerable success in central and southern West Virginia. The process is used also as a substitute for glycerin shooting for the revival of old wells that have declined in production. There are many hundreds of wells in the Big Lime (Greenbrier, Mis.) which eventually will profit from this treatment. The same method may also prove useful in the deep Oriskany (L. Dev.) sand and the Newburg (Sil.), which are frequently calcareous.

The "time-bomb," or dry method, of shooting gas wells, is now frequently employed in southern West Virginia. This method is designed to avoid the use of water or other liquid to hold down the shot. It is

Table 2.—(*Continued*)

	Deepest Horizon Tested	Drilled by	Initial Production per Day: Gas, Millions Cu. Ft.	Pressure, Lb. per Sq. In.: Tubing	Remarks
1	L. Dev.—Helderberg	Godfrey L. Cabot, Inc. (A. D. Huntington, 52)	0		Dry; abandoned.
2	L. Dev.—Oriskany	Columbian Carbon Co. (W. F. Copenhaver, Hrs., 1)	2.7	1900	
3	L. Dev.—Oriskany	Yoak Oil & Gas Co. (Goshorn Hrs., 1)	1.2		
4	Sil.—Red Medina	Benedum-Trees Oil Co. (Joseph A. Hill, 2)	0		Dry; abandoned.
5	L. Dev.—Oriskany	Godfrey L. Cabot, Inc. (G. C. Painter, et al, 1)	0		Dry; before and after shot.
6	L. Dev.—Oriskany	Godfrey L. Cabot, Inc. (Campbell Creek Coal Co., 8)	2.0	1300	
7	L. Dev.—Oriskany	Godfrey L. Cabot, Inc. (Alberta Putney, 1)	0		Dry (small gas show).
8	L. Mis.—Pocono	Godfrey L. Cabot, Inc. (Beaver Coal Co., 9)	0		Dry; abandoned.
9	U. Dev.—Chemung-Benson	Columbian Carbon Co. (I. M. Bennett, 1)	0.4	1480+	
10	U. Dev.—Chemung-Benson	Standard Gas Co. (W. C. Talbott, 1)	0.4		

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	40 (est.)	5 (est.)
Number of oil wells completed during 1935	156	0
Number of gas wells completed during 1935	412	5
Number of dry holes completed during 1935	135	5

described in a letter from Mr. R. C. Lafferty, geologist of the Columbian Carbon Co., as follows:

> Shells are run to the desired position in the well; then a time-bomb, which is a device in which an electrical contact is controlled by a timing mechanism, is run. This time-bomb is generally set for 11 hr., or any desired interval in which enough time will be allowed to complete work on shot before the charge will be set off. An umbrella bridge is then run on top of the time-bomb, after which a calculated amount of sand or gravel is placed on top of the shot. After the shot explodes the gravel, or tamp, is removed.

In exploring for the structural position of the deep Oriskany sand vertical reflection shooting is now employed with rather satisfactory results. In southern West Virginia there are few sandstones or heavy strata of consequence in the shale interval of about 2500 ft. from the Berea sand (basal Mis.) down to the Corniferous lime (Onondaga-Dev.), which overlies the Oriskany. By recording the time return from the Corniferous at a point where its depth is known, dependable results can be obtained at other stations without the confusion of shots that may and does occur in regions where there is no thick shale interval.

TABLE 3.—*Summary of New Development in* 1935 *in West Virginia*

County	Wells Drilled	Oil		Gas		Dry Holes
		No. of Wells	Bbl. per Day	No. of Wells	M. Cu. Ft. per Day	
Boone	46	1	5[1]	42	20,092[2]	3
Braxton	1			1		
Brooke	1					1
Cabell	61	1	28	60	57,703[2]	
Calhoun	74	9	152[2]	52	23,365[2]	13
Clay	8	1	35	6	744[2]	1
Doddridge	8	3	11	3	600	2
Fayette	2			2	672[2]	
Gilmer	32	5	78	25	13,577[2]	2
Hancock	8	3	11	2	200	3
Harrison	4	1	5[1]	3	300	
Kanawha	58	5	66[2]	34	49,788[2]	19
Lewis	2			1		1
Lincoln	14			14	2,992[2]	
Logan	6			4	11,152	2
Marion	9	4	64[2]	5	515[2]	
Marshall	9	2	20[2]	6	3,534[2]	1
Mason	1	1	2			
Mingo	2	1	1			1
Monongalia	10	1	5[1]	7	1,233	2
Pleasants	38	19	106[2]	3	700	16
Putnam	7			6	4,812[2]	1
Raleigh	5			4	1,825	1
Ritchie	137	43	798[2]	60	21,823[2]	34
Roane	69	27	272[2]	29	17,939[2]	13
Tyler	17	6	73[2]	7	2,940[2]	4
Upshur	5			4	2,000[2]	1
Wayne	12	6	14[2]	6	1,060[2]	
Wetzel	19	3	70	11	7,173[2]	5
Wirt	29	6	66[2]	15	6,496[2]	8
Wood	19	8	146[2]	5	2,250[2]	6
Total	713	156	2,028	417	255,485	140

[1] Unknown; assumed as 5 barrels.
[2] Several wells unknown; assumed same as county average of known wells.

TABLE 4.—*Oriskany Sand Wells, Kanawha County, West Virginia*

District	Completed before 1935						Completed in 1935						Completed in January, 1936						Number of Wells Drilling in January, 1936
	Oil		Gas		Dry Holes	Total Number of Wells	Oil		Gas		Dry Holes	Total Number of Wells	Oil		Gas		Dry Holes	Total Number of Wells	
	Number of Wells	Bbl.	Number of Wells	M. Cu. Ft.			Number of Wells	Bbl.	Number of Wells	M. Cu. Ft.			Number of Wells	Bbl.	Number of Wells	M. Cu. Ft.			
Cabin Creek	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0
Elk	1	158	3	373	0	4	0		5	13,846	1	6	0		0		0	0	7
Jefferson	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Loudon	0	0	2	503	1	3	0	0	1	1,400	1	2	0	0	1	300	0	1	2
Poca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Malden	0	0	0	0	0	0	0	0	4	12,395	1	5	0	0	1	4,347	0	1	4
Union	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2
Total Kanawha County	1	158	5	876	2	8	0	0	10	27,641	6	16	0	0	2	4,647	0	2	1

Statistics

A previous paper, by Smith[2], shows a subdivision of the state by fields, and a similar paper by the writer[3] gives a classification by producing areas. The separation by pools, fields, or even producing areas, is mostly a matter of opinion, because of interconnections, and there is no record of production by such boundaries, or even by counties. There is, therefore, no point in repeating these tabulations.

Table 1 shows oil and gas territory, reserves, production, and number of oil and gas wells. The first section of the table, on territory and reserves, represents the considered judgment of the writer, based on long study of the state, and is intended to contradict certain rather widely published figures. There is no complete record of leaseholds but it is known that gas utilities alone held 2,887,626 acres as of Dec. 31, 1934. Territory held by independent gas operators and by oil companies should easily swell the figure to 4,000,000 acres, or more. Some recent estimates of oil reserves are extremely low and wholly ridiculous considering the well sustained annual production. The figure on gas production to date does not include any allowance for losses incident to the production of oil and lack of gas markets in the early years of the industry. This loss has been estimated by the writer as 2,750,000 million cubic feet, and if added to the captured production would give a figure of 8,621,705 million cubic feet. Such losses are scarcely appreciable at the present time, hence the reserve figure of 7,000,000 million cubic feet should represent pipe line gas.

Table 2 shows the most important wildcat wells of 1935. Table 3 is a summary of new development as compiled by the writer from all available sources. Table 4 is a condensed summary of Oriskany sand exploration and development in Kanawha County.

Acknowledgments

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[2] V. C. Smith: Oil and Gas Production in Kentucky, Ohio and West Virginia. *Trans.* A.I.M.E. (1934) **107,** 229–242.

[3] D. B. Reger: Oil and Gas Development in West Virginia during 1934. *Trans.* A.I.M.E., (1935) **114,** 457–469.

Oil Development and Production in Wyoming in 1935

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The oil industry continued relatively quiet in Wyoming in 1935, although production increased about 8 per cent over the previous year; 55 oil wells were completed in 1935, compared to 34 in 1934, and at the end of the year 44 wells were drilling, 33 in proven fields and 11 in wildcat locations. The total drilling a year ago was only 30.

In the year 1935 Wyoming produced a total of 13,451,000 bbl. of oil, a gain of 912,000 bbl. over the 1934 figure of 12,539,000 bbl. Approximately two-thirds of the increase, or 630,000 bbl., was from black oil fields and one-third, or 285,000 bbl., from light oil pools. Salt Creek, with production of 6,357,000 bbl., is still many times the largest field in Wyoming but in 1935 it made less than 50 per cent of the state's total, after producing more than all other fields in the state for 24 years; however, its decline was only 3.8 per cent from the previous year. Oregon Basin, a black oil field, held second place again with production of 1,163,000 bbl., a good increase over 1934. Grass Creek, with increases in both its light and black oil, jumped into third place; and Lance Creek, with its new Sundance light oil production, was in fourth place in the amount of production. Frannie, which was in third place in 1934, dropped far back on the list because of lack of market. Byron and Garland, two other black oil fields in the Big Horn Basin, increased considerably. Big Muddy, a prominent light-oil field, was down with a natural decline; and Elk Basin, also light oil, produced less because of market conditions.

During 1934 only three gas wells were drilled in Wyoming and 29 dry holes, 13 in proven fields and 16 at wildcat locations. Of the latter, 5 were on wildcat structures of considerable interest. Of the 55 wells completed during the year, 53 were in proven fields and of these 17 were small ones in the shallow Osage field and 10 were light-oil wells good for 1500 to 3000 bbl. each in the Lance Creek field.

Discoveries

Two of the oil wells were discoveries at Medicine Bow and Sheep Creek. Medicine Bow is a very large anticline with more than 3500 ft. of closure and is located in Carbon County in the south-central part of the state. In 1923 it showed some oil in the Upper Cretaceous Frontier

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formation but went to water, and the Dakota series also failed to produce. This year a joint test of the Ohio Oil Co. and California Company first reached the Jurassic Sundance formation and discovered 63° gravity light oil and gas in two sands between 5200 and 5450 ft. On short tests, the lower bench flowed 275 bbl. an hour and more than 15,000,000 cu. ft. of gas, and the upper bench 87,000,000 cu. ft. of gas and an estimated flow of 75 bbl. an hour of 63° gravity oil. The well was completed in both sands with a packer on the tubing between them, so that the lower sand can produce through the tubing and the upper sand through the annular space between the casing and the tubing. Since the structure was a very large one, it had possibilities of becoming a major field, but a second well drilled 3/4 mile to the south found water in the lower bench, although it is a good well in the upper bench of the Sundance. It is now generally estimated that the size of the pool will be about 800 acres. It is possible, but not probable, that the pool in the upper bench could cover a greater area.

The other discovery in Wyoming was at Sheep Creek in Fremont County, where the Mid-American Oil Co. found 75 bbl. of 24° gravity black oil in the Permian Embar formation at 2100 ft. The anticline is so steep with dips up to 60° to 70° that two dry holes were drilled before the crest of the fold was located. Since the area must be small and another well has now developed water in the Tensleep sand, Sheep Creek cannot be of great importance.

Two other interesting developments in Wyoming were discoveries of new oil pools in deeper untested sands at Lance Creek, in Niobrara County, and at Quealy, in Albany County. Lance Creek's first production from the sands of the Dakota series was nearly exhausted in 1932 when new oil was found in the upper bench of the Sundance, which yielded wells good for about 500 bbl. initial. In March, 1935, larger production was discovered in the lower bench of the Sundance and 10 wells were rapidly drilled. The pool in the lower bench now covers 1100 acres and is only partly defined, but may not exceed 2000 acres. The upper Sundance pool is smaller. The other new discovery was at Quealy, where light oil was found in 1934 in the Muddy sand. The discovery well was deepened in 1935 to the Dakota sand and pumped 1000 bbl. A second well found the same production in the Dakota, but when deepened to test the Sundance, unexpectedly encountered very steep dips in the intervening Morrison formation and failed to reach the Sundance. A new well is now being drilled for that purpose.

Waugh dome, in Hot Springs County, discovered at the very end of 1934, with a 600-bbl. black-oil well in the Embar lime, has proved somewhat disappointing to date. The well marketed nearly 100,000 bbl. of oil in 1935 but showed considerable water with the oil; an offset well has

TABLE 1.—*Oil and Gas Production in Wyoming during* 1935

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Oil and Gas[a]	Gas	Total	Total Oil Production, Bbl.: To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
1	Alkali Butte, *Fremont*	7	40		300	300	8,130	0	0	0
2	Allen Lake, *Carbon*	2	0	0	200	200				
3	Ant Hills, *Niobrara*	8	40	0	0	40	7,378	0	0	0
4	Badger Basin, *Park*	5	200	0	0	200	72,550	14,650	12,200	40
	Baxter Basin, *Sweetwater*									
5	Frontier	13			7,467	7,467				
6	Dakota	13			4,310	4,310				
7	Total	13			7,467	7 467				
	Big Muddy, *Converse*									
8	Shannon	19	2,000			2,000	1,xxx,xxx	x	x	x
9	Wall Creek	19	2,600			2,600	23,70x,xxx	58x,xxx	520,xxx	y
10	Dakota	13	400			400	55x,xxx	4x,xxx	50,xxx	y
11	Total	19	2,600			2,600	24,252,000	628,000	569,000	1,573
	Big Sand Draw, *Fremont*									
12	Wall Creek	18			1,200	1,200				
13	Morrison	5			300	300				
14	Total	18			1,200	1,200				
15	Billy Creek, *Johnson*	14			700	700				
	Black Mountain, *Hot Springs*									
16	Embar	10	60			60	47,xxx	22,xxx	25,xxx	0
17	Tensleep	12	300			300	66,xxx	26,xxx	40,xxx	0
18	Total	12	360			360	113,500	48,6xx	65,000	0
	Bolton Creek, *Natrona*									
19	Sundance	15	50			50	3x,xxx	0	0	0
20	Embar	15	50			50	1x,xxx	0	0	0
21	Total	15	50			50	45,640	0	0	0
22	Boone, *Natrona*	15			300	300				
	Byron (East Byron), *Big Horn*									
23	Frontier	13			500	500				
24	Sundance	6	40			40	14,000	0	0	0
25	Tensleep	3	600			600	492,000	111,000	335,000	1,200
26	Total	13	600		500	600	506,000	111,000	335,000	1,200
27	Circle, *Fremont*	12	250			250	0	0	0	0
28	Dallas-Derby, *Fremont*	52	350			350	2,081,500	218,500	205,000	445
	Dutton Creek, *Carbon*									
29	Shannon	9			800	800				
30	Muddy	9	150			150	179,900	27,200	19,700	33
31	Total	9	150		800	800	179,900	27,200	19,700	33
	East Mahoney, *Carbon*									
32	Dakota	14			3,100	3,100				
33	Sundance	10			3,500	3,500				
34	Total	14			3,500	3,500				
35	Eight Mile Lake, *Carbon*	12			250	250				
	Elk Basin, *Park*									
36	Frontier	20	580			580	10,357,000	201,600	106,400	500
37	Dakota	14			1,200	1,200				
38	Total	20	580		1,200	1,200	10,357,000	201,600	106,400	500
39	Enos Creek, *Hot Springs*	12			500	500				
40	Ferris, *Carbon*	18		200		200	476,720	7,120	7,800	17
41	Fourbear, *Park*	7	500			500	0	0	0	0
	Frannie, *Park*									
42	Tensleep	7	500			500	1,449,150	622,400	152,750	625
43	Madison	6	10			10	75,250	6,000	5,250	15
44	Total	7	510			510	1,524,400	628,400	158,000	640
	Garland, *Big Horn*									
45	Frontier	28	40			40	340,000	0	0	0
46	Dakota	16			1,200	1,200				
47	Embar-Tensleep	8			1,650	1,650				
48	Madison	4		960		960	1,163,400	249,000	421,400	775
49	Total	28		960	1,650	1,650	1,543,400	249,000	421,400	775
50	Golden Eagle, *Hot Springs*	16			120	120				

[a] Footnotes to column heads and explanation of symbols are given on page 215.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.: Per Acre to End of 1935[b]	Average Oil Production, Bbl.: Per Well Daily during Nov., 1935	Total Gas Production, Millions Cu. Ft.: To End of 1935	Total Gas Production, Millions Cu. Ft.: During 1934	Total Gas Production, Millions Cu. Ft.: During 1935	Total Gas Production, Millions Cu. Ft.: Maximum Daily during 1935	Number of Oil and/or Gas Wells: Completed to End of 1935	Number of Oil and/or Gas Wells: During 1935: Completed	Number of Oil and/or Gas Wells: During 1935: Abandoned	Number of Oil and/or Gas Wells: At End of 1935: Temporarily Shut Down	Number of Oil and/or Gas Wells: At End of 1935: Producing Oil Only	Number of Oil and/or Gas Wells: At End of 1935: Producing Oil and Gas[c]	Number of Oil and/or Gas Wells: At End of 1935: Producing Gas Only	Number of Oil and/or Gas Wells: At End of 1935: Total Producing
1	200	0	0	0	0	0	3	0	0	3	0	0	0	0
2			750	100	650[1]	y	3	0	0	0	0	0	3	3
3	180	0					1	0	0	1	0	0	0	0
4	360	40					1	0	0	0	1	0	0	1
5			y	y	y	y	9	1	0	0	0	0	9	9
6			y	y	y	y	11	0		0	0	0	11	11
7			12,200	2,400	2,800[1]	y	20	1	0	0	0	0	20	20
8	500	x					35	0	0	25	10	0	0	10
9	9,115	y					134	0	0	4	130	0	0	130
10	1,400	y					5	1	0	0	5	0	0	5
11	9,300	30					174	1	0	29	145	0	0	145
12			39,000	2,250	2,750[1]	y	10	0	0	0	0	0	10	10
13			0	0	0	0	1	0	0	1	0	0	0	0
14			39,000	2,250	2,750[1]	y	11	0	0	1	0	0	10	10
15			1,630	230	300[1]	y	8	0	0	0	0	0	8	8
16	800	0					2	0	0	0	2	0	0	2
17	220	0					4	0	0	0	4	0	0	4
18	305	0					6	0	0	0	6	0	0	6
19	700	0					3	0	0	3	0	0	0	0
20	200	0					1	0	0	1	0	0	0	0
21	900	0					4	0	0	4	0	0	0	0
22			4,030	70	60[1]	y	4	0	0	2	0	0	2	2
23			2,500	100	200[1]	y	2	0	0	0	0	0	2	2
24	350	0					1	0	0	1	0	0	0	0
25	820	240					5	3	0	0	5	0	0	5
26	840	240	2,500	100	200[1]	y	8	3	0	1	5	0	2	7
27	0	0					2	0	0	2	0	0	0	0
28	5,920	9					50	0	0	2	48	0	0	48
29			825	200	200[1]	y	5	0	0	0	0	0	5	5
30	1,200	11					3	0	0	0	3	0	0	3
31	1,200	11	825	200	200[1]	y	8	0	0	0	3	0	5	8
32			8,020	10	20[1]	y	2	0	0	0	0	0	2	2
33			15,630	200	630[1]	y	11	0	0	0	0	0	11	11
34			23,650	210	650[1]	y	13	0	0	0	0	0	13	13
35			4,660	50	60[1]	y	4	0	0	3	0	0	1	1
36	17,700						149	0	0	65	84	0	0	84
37			19,255	1,400	1,550[1]	y	5	0	0	1	0	0	4	4
38	17,000		19,255	1,400	1,550[1]	y	154	0	0	66	84	0	4	88
39			0	0	0	0	1	0	0	1	0	0	0	0
40	2,380	2	y	y	y	y	8	0	0	0	8	0	0	8
41	0	0					1	0	0	1	0	0	0	0
42	2,900	156					13	2	0	9	4	0	0	4
43	7,500	15					1	0	0	0	1	0	0	1
44	2,980	130					14	2	0	9	5	0	0	5
45	8,500	0					3	1	1	3	0	0	0	0
46			20,125	125	125[1]	y	10	0	0	6	0	0	4	4
47			1,750	350	450[1]	y	2	0	0	1	0	0	1	1
48	1,210	200	0	0	0[1]	0	4	1	0	0	4	0	0	4
49	1,600	200	21,875	475	575[1]	y	19	2	1	10	4	0	5	9
50			2,250	0	0	0	0	0	0	0	0	0	0	0

[1] All 1935 gas figures are estimates only.

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1935			Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935				
			Number of Wells				Average at End of		Gravity A.P.I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Initial	1934	1935	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	4,600	4,570	0	1	0	*y*	*y*	*y*	*x*	*x*	36	0	M
2	2,175	2,100				*y*	*y*	*y*					
3	3,957	3,951	0	0	0	*x*	*x*	*x*	*x*	*x*	36	0.1	M
4	8,500	8,250	0	1	0	*x*	*x*	*x*	*y*	*y*	48	0	P
5	2,400	2,350				800	*y*	*y*					
6	3,000	2,950				775	*y*	*y*					
7													
8	1,250	1,200	0	10	0	*x*	*x*	*x*	*y*	*y*	31	*y*	M
9	3,400	3,260	0	130	0	*x*	*x*	*x*	*y*	*y*	32	0.17	M
10	4,700	4,600	0	5	0	*x*	*x*	*x*	*y*	*y*	36	0.18	M
11			0	145	0								
12	2,800	2,300				1,100–1,300	*y*	*y*					
13	4,350	4,300				*x*	*x*	*x*					
14													
15	3,250	3,200				1,150	*y*	*y*					
16	2,950	2,900	0	2	0	*x*	*x*	*x*	*y*	*y*	25	2.8	A
17	3,350	3,170	0	4	0	*x*	*x*	*x*	*y*	*y*	23	2.9	A
18			0	6	0	*x*	*x*	*x*					
19	1,120	1,100	0	3	0	*x*	*x*	*x*	*y*	*y*	22	2.8	A
20	2,050	2,025	0	1	0	*x*	*x*	*x*	*y*	*y*	32	3.0	A
21			0	4	0	*x*	*x*	*x*					
22	2,200	2,150				*y*	*y*	*y*					
23	2,500	2,400				1,000	*y*	*y*					
24	4,209	4,205	0	0	0	*x*	*x*	*x*	*x*	*x*	32	0.38	M
25	5,400	5,300	0	5	0	*y*	*y*	*y*	*y*	*y*	25	2.2	A
26			0	5	0								
27	655	170	0	2	0	*x*	*x*	*x*	*x*	*x*	23	*y*	A
28	1,200	700	0	50	0	*x*	*x*	*x*	*y*	*y*	23	2.4	A
29	1,700	1,600				450	*y*	*y*					
30	4,900	4,850	0	3	0	*x*	*x*	*x*	*y*	*y*	34	0.3	M
31			0	3	0								
32	2,300	2,200				700	*y*	*y*					
33	2,700	2,600				1,140	*y*	*y*					
34													
35	3,500	3,400				1,600	*y*	*y*					
36	1,200	1,000	0	84	0	*x*	*x*	*x*	*y*	*y*	43	0.14	P
37	2,500	2,400				925	*y*	*y*					
38			0	84	0								
39	2,850	2,600				790	*x*	*x*					
40	1,650	1,600	0	8	0	*y*	*y*	*y*	*y*	*y*	36	0.45	M
41	3,350	3,270	0	0	0	*y*	*y*	*y*	*x*	*x*	15	*y*	A
42	2,800	2,770	0	13	0	*x*	*x*	*x*	*y*	*y*	28	2.5	A
43	3,013	3,012	1	0	0	*x*	*x*	*x*	*y*	*y*	18	3.3	A
44			1	13	0								
45	900	700	0	0	0	*x*	*x*	*x*	*y*	*y*	42	*y*	P
46	1,600	1,500				*x*	*y*	*y*					
47	3,200	3,000				1,450	*y*	*y*					
48	4,400	4,000	4	0	0	*y*	*y*	*y*	*y*	*y*	19	3.0	A
49			4	0	0								
50	3,000	2,050				1,175	exhausted						

TABLE 1.—*(Continued)*

Line Number	Character of Gas, Approx. Average during 1935		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1	y	y	Morrison	Jur	S	Por	30	A	18	Chugwater	5,460
2	y	y	Sundance	Jur	S	Por	40	A	3	Chugwater	4,083
3			Dakota	CreU	S	Por	6	A	2	Lakota	4,257
4	x	x	Frontier	CreU	S	Por	40	A	0	Frontier	8,725
5	y	y	Frontier	CreU	S	Por	16	AF			
6	1,040	y	Dakota	CreU	S	Por	50	AF			
7									5	Nugget	3,822
8		y	Shannon	CreU	S	Por	65	A			
9		y	Wall Creek	CreU	S	Por	100	A			
10		y	Dakota	CreU	S	Por	15	A			
11								A	226	Madison	6,597
12	1,020	y	Wall Creek	CreU	S	Por	150	A			
13	x	x	Morrison	Jur	S	Por	22	A			
14									3	Sundance	5,345
15	890	y	Frontier	CreU	SH	Por	20	A	5	Muddy sand	4,400
16			Embar	Per	L	Cav	35	A			
17			Tensleep	Pen	S	Por	100	A			
18									2	Madison	3,832
19			Sundance	Jur	S	Por	10	Af			
20			Embar	Per	L	Cav	15	Af			
21									11	Amsden	2,867
22	y	y	Shannon	CreU	S	Por	70	A	1	Niobrara	5,200
23	y	y	Frontier	CreU	S	Por	30	AF			
24			Sundance	Jur	S	Por	4	AF			
25			Tensleep	Pen	S	Por	70	AF			
26								AF	3	Amsden	5,505
27			Tensleep	Pen	S	Por	50	A	0	Tensleep	650
28			Embar-Tensleep	Per-Pen	L-S	Cav-Por	150	A	23	Tensleep	1,400
29	y	y	Shannon	CreU	S	Por	40	A			
30			Muddy	CreU	S	Por	30	A			
31									1	Lakota	5,075
32	y	y	Dakota	CreU	S	Por	30	A			
33	y	y	Sundance	Jur	S	Por	110	A			
34								A	5	Sundance	3,100
35	y	y	Dakota	CreU	S	Por	50	A	4	Chugwater	4,560
36	y	y	Frontier	CreU	S	Por	40	AF			
37	y	y	Dakota	CreU	S	Por	55	AF			
38								AF	39	Dakota	2,450
39	x	x	Frontier	CreU	S	Por	40	A	0	Dakota	3,992
40	y	y	Mowry-Dakota	CreU	S	Por	25	A	8	Tensleep	4,600
41			Tensleep	Pen	S	Por	60	A	1	Tensleep	3,350
42			Tensleep	Pen	S	Por	100	AF			
43			Madison	Mis	L	Cav	x	AF			
44									4	Madison	3,230
45			Frontier	CreU	S	Por	35	AF			
46	y	y	Dakota	CreU	S	Por	50	AF			
47	y	y	Embar-Tensleep	Per-Pen	L-S	Cav-Por	100	AF			
48	y	y	Madison	Mis	L	Cav	200?	AF			
49									83	Madison	4,424
50	x	x	Mesaverde	CreU	S	Por	50	A	5	Cody	4,019

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Area Proved, Acres: Oil and Gas[a]	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1935	Total Oil Production, Bbl.: During 1934	Total Oil Production, Bbl.: During 1935	Daily Average during Nov., 1935
	Grass Creek, *Hot Springs*									
51	Frontier	21	1,400			1,400	23,303,500	345,000	509,500	2,250
52	Embar-Tensleep	14	900			900	1,494,500	0	210,500	0
53	Total	21	1,400			1,400	24,798,000	345,000	720,000	2,250
54	Greybull, *Big Horn*	27	640			640	245,150	1,150	450	0
	Hamilton, *Hot Springs*									
55	Embar	17	640			640	3,758,000	303,000	421,000	850
56	Tensleep	6	300			300	0	0	0	0
57	Total	17	640			640	3,758,000	303,000	421,000	850
58	Hidden Dome, *Washakie*	18	60		640	700	30,000	7,500	20,000	90
59	Labarge, *Lincoln, Sublette*	12	950			950	4,301,000	440,000	450,000	1,225
60	Lake Creek, *Hot Springs*	10	100			100	0	0	0	0
	Lance Creek, *Niobrara*									
61	Dakota	13		1,500		1,500	4,314,000	50,000	50,000	136
62	Sundance	5	1,100			1,100	670,000	71,000	599,000	2,064
63	Total	13	1,100	1,500		1,500	4,984,000	121,000	649,000	2,200
	Lander (Hudson), *Fremont*									
64	Embar	17	340			340	665,000	7,000	15,000	30
65	Tensleep	9	110			110	982,000	101,000	98,000	260
66	Total	17	340			340	1,647,000	108,000	113,000	290
67	Little Buffalo Basin, *Hot Springs Park*	21			4,800	4,800				
68	Little Grass Creek, *Hot Springs*	19			160	160				
69	Little Polecat, *Park*	17			500	500				
	Lost Soldier, *Sweetwater*									
70	Frontier	19	200			200	2,000,000	120,000	100,000	190
71	Dakota-Lakota	13	350			350	11,266,500	283,000	93,500	250
72	Sundance	9	100			100	4,200,000	270,000	355,000	860
73	Tensleep	5	100			100	506,000	4,000	6,000	0
74	Total	19	350			350	17,972,500	577,000	554,500	1,300
	Mahoney Dome, *Carbon*									
75	Dakota	16			1,400	1,400				
76	Sundance	11			1,660	1,660				
77	Tensleep	6	200			200	0	0	0	0
78	Total	16	200		1,660	1,660	0	0	0	0
79	Maverick Springs, *Fremont*	18	1,400			1,400	0	0	0	0
80	Medicine Bow, *Carbon*	1		800		800	0	0	0	0
81	Midway, *Natrona*	5	200			200	150,800	34,000	22,800	63
	Mule Creek, *Niobrara*									
82	Lakota	15	220			220	1,194,000	7,*xxx*	*y*	0
83	Minnelusa	5	100			100	3,750	2,*xxx*	*y*	0
84	Total	15	220			220	1,197,750	9,*xxx*	3,750	0
85	Muskrat, *Fremont*	8			500	500				
	North Baxter, *Sweetwater*									
86	Dakota	8			1,200	1,200				
87	Sundance	8			3,700	3,700				
88	Total	8			3,700	3,700				
89	North Byron, *Park*	20			800	800				
90	North Casper Creek, *Natrona*	5	100			100	1,874	C	0	0
91	North Sunshine, *Park*	8	150			150	0	0	0	0
92	Notches, *Natrona*	13	400			400	170,000	0	0	0
	Oregon Basin, *Park*									
93	Dakota	23			1,300	1,300				
94	Embar-Tensleep	9	10,000			10,000	6,266,000	798,000	1,163,000	2,930
95	Total	9	10,000		1,300	10,000	6,266,000	798,000	1,163,000	2,930
96	Osage, *Weston*	15	10,000			10,000	3,392,000	297,000	250,000	640
	Pilot Butte, *Fremont*									
97	Niobrara	19	250			250	522,000	9,500	9,800	27
98	Muddy	6			400	400				
99	Total	19	250		400	650	522,000	9,500	9,800	27
100	Pine Mountain, *Natrona*	16			100	100				

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
								During 1935		At End of 1935				
	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
51	16,620						316	0	0	11	305	0	0	305
52	1,660	0					12	1	0	12	0	0	0	0
53	17,750						328	1	0	23	305	0	0	305
54	380	0					14	0	0	14	0	0	0	0
55	5,900	27					31	2	0	0	31	0	0	31
56	0	0					1	0	0	1	0	0	0	0
57	5,900	27					32	2	0	1	31	0	0	31
58	500	30	24,000	0	0	0	8	1	2	5	3	0	0	3
59	4,530	13					110	8	0	17	93	0	0	93
60	0	0					1	0	0	1	0	0	0	0
61	2,876	34	58,900	1,600	900[1]	y	14	0	0	0	4	0	6	10
62	600	172	2,000	0	2,000[1]	y	12	10	0	0	2	10	0	12
63	3,300	130	60,900	1,600	2,900[1]	y	26	10	0	0	6	10	6	22
64	1,950	5					31	0	0	25	6	0	0	6
65	8,920	52					5	0	0	0	5	0	0	5
66	4,850	22					36	0	0	25	13	0	0	13
67			13,150	725	1,050[1]	y	10	0	0	2	0	0	8	8
68			1,235	125	135[1]	y	2	0	0	1	0	0	1	1
69			525	100	125[1]	y	1	0	0	0	0	0	1	1
70	10,000	6					45	3	0	15	30	0	0	30
71	32,190	10					27	0	0	3	24	0	0	24
72	42,000	172					5	0	0	0	5	0	0	5
73	5,060	0					1	0	0	1	0	0	0	0
74	51,350	22					78	3	0	19	59	0	0	59
75			14,300	10	100[1]	y	1	0	0	0	0	0	1	1
76			40,850	1,000	650[1]	y	9	0	0	0	0	0	9	9
77	0	0					1	0	0	1	0	0	0	0
78	0	0	55,150	1,010	750[1]	y	11	0	0	1	0	0	10	10
79	0	0					32	0	0	32	0	0	0	0
80	0	0	0	0	0	0	1	1	0	1	0	0	0	0
81	750	63					3	0	0	2	1	0	0	1
82	5,430	0					37	0	0	37	0	0	0	0
83	37	0					1	0	0	1	0	0	0	0
84	5,435	0					38	0	0	38	0	0	0	0
85			2,725	425	400[1]	y	1	0	0	0	0	0	1	1
86			y	y	y	y	3	0	0	0	0	0	3	3
87			y	y	y	y	2	0	0	0	0	0	2	2
88			5,600	1,500	2,000[1]	y	5	0	0	0	0	0	5	5
89			12	3	4	y	4	0	0	3	0	0	1	1
90	18	0					2	0	0	2	0	0	0	0
91	0	0					1	0	0	1	0	0	0	0
92	425	0					3	0	0	3	0	0	0	0
93			1,265	125	140[1]	y	4	1	1	0	0	0	4	4
94	1,626	90					35	1	0	2	33	0	0	33
95	1,626	90	1,265	125	140[1]	y	39	2	1	2	33	0	4	37
96	339	2					416	17	8	56	360	0	0	360
97	2,100	2					11	0	0	0	11	0	0	11
98			0	0	0	0	2	0	0	2	0	0	0	0
99	2,100	2	0	0	0	0	13	0	0	2	11	0	0	11
100			0	0	0	0	2	0	0	2	0	0	0	0

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1935			Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935				
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells			Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]
			Flowing	Pumping	Gas-lift		1934	1935	Maximum	Minimum	Weighted Average		
51	1,200	800	0	305	0	x	x	x	y	y	44	0.14	P
52	4,000	3,600		0	0	x	x	x	x	x	23	2.6	A
53			0	305	0								
54	1,050	1,000	0	0	0	x	x	x	y	y	48	0	P
55	2,600	2,300	0	31	0	x	x	x	26	18	23	2.3	A
56	2,860	2,700	0	0	0	x	x	x	y	y	21	3.0	A
57			0	31	0								
58	1,600	1,200	0	3	0	490	exhausted		x	x	43	y	P
59	1,000	650	0	93	0	x	x	y	45	19	28	0.18	M
60	3,760	3,730	0	1	0	x	x	x	x	x	26	3.2	A
61	3,200	2,900	0	5	0	1,175	y	y	y	y	42	0.14	P
62	3,700	3,650	10	2	0	y	y	y	y	y	41	0.14	P
63			10	7	0								
64	1,500	1,300	0	6	0	x	x	x	y	y	21	2.3	A
65	1,800	1,700	0	5	0	x	x	x	y	y	23	2.9	A
66			0	13	0								
67	1,500	1,200				445	y	y					
68	2,700	2,650				850	y	y					
69	4,100	3,900				1,425	y	y					
70	600	300	0	30	0	x	x	x	y	y	30	y	M
71	1,700	1,500	0	24	0	x	x	x	y	y	32	0.2	M
72	2,150	1,950	0	3	2	x	x	x	y	y	32	y	M
73	4,000	3,900	0	0	0	x	x	x	y	y	35	y	M
74			0	57	2	x	x	x					
75	2,300	2,200				825	y	y					
76	2,700	2,600				1,170	y	y					
77	4,760	4,600	0	1	0	x	x	x	x	x	34	1.3	M
78			0	1	0								
79	1,700	1,450	0	0	0	x	x	x	x	x	22	2.9	A
80	5,450	5,200	1	0	0	y	y	y	x	x	63	y	P
81	5,250	5,200	0	1	0	x	x	x	x	x	32	0.3	M
82	1,550	1,500	0	0	0	x	x	x	x	x	32	0.17	M
83	3,180	3,170	0	0	0	x	x	x	x	x	26	2.4	A
84													
85	4,400	4,350				1,450	y	y					
86	3,000	2,950				1,335	y	y					
87	3,400	3,350				1,485	y	y					
88													
89	2,400	2,200				400	y	y					
90	3,210	3,200	0	0	0	x	x	x	x	x	23	y	A
91	3,700	3,475	0	0	0	x	x	x	x	x	16	3.9	A
92	2,850	2,800	0	0	0	x	x	x	x	x	23	1.7	A
93	1,550	1,500				700	y	y					
94	3,900	3,500	0	33	0	x	x	x	y	y	21	3.3	A
95			0	33	0								
96	1,525	1,500	0	360	0	x	x	x	y	y	41	0.10	P
97	1,000	800	0	11	0	x	x	x	y	y	36	0.1	P
98	3,370	3,350				800	x	x					
99			0	11	0								
100	1,840	1,830	0	0	0	700	x	x					

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1935		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
51			Frontier	CreU	S	Por	200	A			
52			Embar-Tensleep	Per-Pen	L-S	Cav-Por	200	A			
53								A	85	Amsden	4,336
54			Greybull	CreU	S	Por	20	MC	115	Tensleep	2,950
55			Embar	Per	L	Cav	50	Af			
56			Tensleep	Pen	S	Por	60	Af			
57									2	Tensleep	2,886
58	y	y	Frontier	CreU	S	Por	120	A	8	Morrison	2,785
59	y	y	Wasatch	Eoc	S	Por	150	A	53	Hilliard	4,210
60	x	x	Embar	Per	L	Cav	30	A	2	Tensleep	3,830
61	y	y	Dakota	CreU	S	Por	70	A			
62	y	y	Sundance	Jur	S	Por	65	A			
63									55	Chugwater	3,900
64			Embar	Per	L	Cav	60	A			
65			Tensleep	Pen	S	Por	125	A			
66									8	Tensleep	2,190
67	1,000	y	Frontier	CreU	S	Por	100	A	4	Mowry	1,670
68	y	y	Frontier	CreU	S	Por	50	A	0	Frontier	2,915
69	y	y	Frontier	CreU	S	Por	15	A	0	Frontier	4,420
70			Frontier	CreU	S	Por	100	Af			
71			Dakota-Lakota	CreU, L	S	Por	80	Af			
72			Sundance	Jur	S	Por	200	Af			
73			Tensleep	Pen	S	Por	65	Af			
74									37	Tensleep	4,009
75	y	y	Dakota	CreU	S	Por	30	A			
76	y	y	Sundance	Jur	S	Por	110	A			
77			Tensleep	Pen	S	Por	160	A			
78									6	Tensleep	4,690
79			Embar	Per	L	Cav	50	A	3	Tensleep	2,094
80	y	y	Sundance	Jur	S	Por	140	A	6	Chugwater	5,910
81			Wall Creek	CreU	S	Por	30	A	4	Chugwater	6,689
82			Lakota	CreL	S	Por	25	A			
83			Minnelusa	Pen	L	Cav	10	A			
84									11	Minnelusa	3,185
85	y	y	Frontier	CreU	S	Por	35	AF	1	Chugwater	6,081
86	y	y	Dakota	CreU	S	Por	20	AF			
87	y	y	Sundance	Jur	S	Por	15	AF			
88									5	Sundance	3,800
89	y	y	Frontier	CreU	S	Por	30	AF	1	Frontier	2,800
90			Tensleep	Pen	S	Por	5	A	2	Tensleep	3,308
91			Tensleep	Pen	S	Por	60	A	1	Tensleep	3,712
92			Tensleep	Pen	S	Por	40	A	4	Tensleep	2,830
93	y	y	Dakota	CreU	S	Por	35	A			
94			Embar-Tensleep	Per-Pen	L-S	Cav-Por	150	A			
95								A	8	Madison?	4,160
96			Newcastle	CreU	S	Por	10	ML	464	Minnelusa	2,150
97			Niobrara	CreU	H	Fis	x	A			
98	y	y	Muddy	CreU	S	Por	18	A			
99									45	Sundance	4,630
100	y	y	Tensleep	Pen	S	Por	25	A	13	Deadwood	3,127

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Area Proved, Acres: Oil and Gas[a]	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1935	Total Oil Production, Bbl.: During 1934	Total Oil Production, Bbl.: During 1935	Daily Average during Nov., 1935
101	Pitchfork, *Park*	5	300			300	0	0	0	0
102	Plunkett, *Fremont*	14	45			45	11,700	0	0	0
103	Poison Spider, *Natrona*	17		400		400	670,000	108,000	55,000	160
104	Powder River, *Natrona*	5			150	150				
105	Quealy, *Albany*	2	160			160	0	0	0	0
106	Rex Lake, *Albany*	12	200			200	216,200	8,200	3,000	0
	Rock Creek, *Carbon*									
107	Dakota	18	1,300			1,300	15,954,000	540,000	514,000	1,360
108	Sundance	1	80			80	30,000	0	30,000	200
109	Total	18	1,300			1,300	15,984,000	540,000	544,000	1,560
	Salt Creek, *Natrona*									
110	1st Wall Creek	27	4,350			4,350	46,505,000	450,000	305,000	777
111	2nd Wall Creek	18	21,450			21,450	198,158,000	5,000,000	4,858,000	13,373
112	Lakota	11	2,030			2,030	15,185,000	675,000	685,000	1,730
113	Sundance	10	660			660	5,062,000	475,000	502,000	1,320
114	Tensleep	5	640			640	65,000	0	0	0
115	Total	27	21,450			21,450	265,000,000	6,600,000	6,350,000	17,200
116	Shannon, *Natrona*	46	200			200	55,400	0	0	0
117	Sheep Creek, *Fremont*	1	100			100	0	0	0	0
118	Simpson Ridge, *Carbon*	11	160			160	159,000	0	0	0
119	South Casper Creek, *Natrona*	13	240			240	2,134,650	79,650	78,600	0
120	South Sunshine, *Park*	9	300			300	0	0	0	0
121	Spindletop, *Natrona*	7	80			80	0	0	0	0
122	Spring Creek, *Park*	6	250			250	0	0	0	0
123	Spring Valley, *Uinta*	35	400			400	54,500	2,100	3,000	10
	Teapot Dome, *Natrona*									
124	Wall Creek	13	640	2,000		2,640	3,000,000	0	0	0
125	Shale	13	*x*			*x*	687,000	8,800	8,200	23
126	Total	13	640	2,000		2,640	3,687,000	8,800	8,200	23
127	Torchlight, *Big Horn*	20	600			600	96,000	0	0	0
128	Warm Springs, *Hot Springs*	18	200			200	257,150	0	41,000	170
129	Waugh, *Hot Springs*	2	100			100	92,000	0	92,000	0
	Wertz, *Carbon*									
130	Frontier	10			100	100				
131	Dakota	15			500	500				
132	Lakota	8			500	500				
133	Sundance	6			200	200				
134	Total	15			500	500				
135	Total Wyoming		61,495	5,860	33,897	96,382	399,021,800	12,539,470	13,451,600	40,289

failed to produce any oil, but work on it has not yet been stopped.

Another new development was the finding of oil-saturated cores in the Tensleep sand on the north end of the large Garland anticline, where several wells have developed big gas flows on the crest of the structure from the Embar and Tensleep and oil from the underlying Madison lime. The well has not cored deeper into the sand or tested because of mechanical difficulties, but offers some hope that commercial oil may be found in the Tensleep sand around and below the gas pool. At Big Muddy, in Converse County, a deep test found water in the Sundance, Tensleep and Madison, and was plugged back to the Dakota.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
							Completed to End of 1935	During 1935		At End of 1935				
	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
101	0	0					1	0	0	1	0	0	0	0
102	260	0					0	0	0	0	0	0	0	0
103	1,675	15	5,600	0	0	0	18	1	0	7	11	0	0	11
104			0	0	0	0	1	0	0	1	0	0	0	0
105	0	0					2	1	0	2	0	0	0	0
106	1,080	0					4	0	0	4	0	0	0	0
107	12,270	30					62	0	0	17	45	0	0	45
108	360	65					3	3	0	0	3	0	0	3
109	12,300	32					65	3	0	17	48	0	0	48
110	10,690	4					362	0	22	171	191	0	0	191
111	9,238	12					1,560	0	5	417	1,143	0	0	1,143
112	7,480	40					63	0	15	20	43	0	0	43
113	7,600	38					44	0	1	9	35	0	0	35
114	100	0					1	0	0	1	0	0	0	0
115	12,350	12					2,030	0	43	618	1,412	0	0	1,412
116	277	0					0	0	0	0	0	0	0	0
117	0	0					2	2	0	2	0	0	0	0
118	1,000	0					0	0	0	0	0	0	0	0
119	8,900	0	11,292	0	0	0	17	0	0	17	0	0	0	0
120	0	0					1	0	0	1	0	0	0	0
121	0	0					3	0	0	3	0	0	0	0
122	0	0					1	0	0	1	0	0	0	0
123	140	1					30	1	0	20	10	0	0	10
124	4,700	0	x	0	0	0	47	0	0	47	0	0	0	0
125	x	12					15	0	0	13	2	0	0	2
126	4,700	12	x	0	0	0	62	0	0	60	2	0	0	2
127	160	0					0	0	0	0	0	0	0	0
128	1,285	17					37	0	0	27	10	0	0	10
129	920	0					1	0	0	1	0	0	0	0
130			700	0	0	0	0	0	0	0	0	0	0	0
131			33,500	400	500[l]	y	3	0	0	0	0	0	3	3
132			22,400	2,400	1,900[l]	y	3	1	0	0	0	0	3	3
133			1,400	0	200[l]	y	1	0	0	0	0	0	1	1
134			58,000	2,800	2,600[l]	y	7	1	0	0	0	0	7	7
135		15	372,080	16,048	19,900[l]	y	4,014	55	55	1,168	2,717	10	117	2,844

PRODUCTION PRACTICE

Oil-production practice has changed little in Wyoming in 1935. More attention is paid to gas drive or recirculation of gas, and it has been successfully used at Salt Creek, Labarge, Rock Creek, Lost Soldier, Elk Basin and Grass Creek. This year's report shows a great increase in wells shut down temporarily and a corresponding decrease in wells on production. These represent wells with high gas-oil ratio that have been shut in to conserve gas. Previous annual lists in this publication did not accurately report this situation; the number of shut-in wells has steadily

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1935			Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1935				
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells			Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]
			Flowing	Pumping	Gas-lift		1934	1935	Maximum	Minimum	Weighted Average		
101	3,900	3,750	0	0	0	*x*	*x*	*x*	*x*	*x*	18	0.35	A
102	500	250	0	0	0	*x*	*x*	*x*	*x*	*x*	42	0.19	P
103	1,425	1,400	0	11	0	525	*x*	*x*	*y*	*y*	22	2.8	A
104	1,350	1,315				530	*y*	*y*					
105	3,320	3,260	0	2	0	*y*	*y*	*y*	*y*	*y*	35	*y*	M
106	3,900	3,800	0	0	0	*x*	*x*	*x*	*y*	*y*	34	0.37	M
107	2,800	2,600	0	45	0	*x*	*x*	*x*	*y*	*y*	35	0.26	M
108	3,250	3,150	0	3	0	*x*	*x*	*x*	*y*	*y*	33	*y*	M
109			0	48	0								
110	1,100	1,000	0	191	0	*x*	*x*	*x*	*y*	*y*	36	0.15	M
111	1,575	1,575	0	1,143	0	*x*	*x*	*x*	*y*	*y*	36	0.16	M
112	2,350	2,300	0	43	0	*x*	*x*	*x*	*y*	*y*	35	0.4	M
113	2,875	2,750	19	16	0	*x*	*x*	*x*	*y*	*y*	35	1.3	M
114	3,980	3,790	0	0	0	*x*	*x*	*x*	*x*	*x*	28	2.3	A
115			19	1,393	0								
116	900	800	0	0	0	*x*		*x*	*x*	*x*	24	*y*	A
117	2,100	2,035	0	0	0	*x*		*x*	*x*	*x*	24	*y*	A
118	675	625	0	0	0	*x*	*x*	*x*	*x*	*x*	21	0.17	A
119	2,700	2,600	0	0	0	*x*	*x*	*x*	*x*	*x*	15	4.5	A
120	2,514	2,475	0	0	0	*x*	*x*	*x*	*x*	*x*	18	*y*	A
121	1,125	1,100	0	0	0	*x*	*x*	*x*	*x*	*x*	22	3.24	A
122	4,250	3,900	0	0	0	*x*	*x*	*x*	*x*	*x*	16	*y*	A
123	900	400	0	10	0	*x*	*x*	*x*	*x*	*x*	38	*y*	M
124	2,950	2,900	0	0	0	*x*	*x*	*x*	*x*	*x*	35	0.15	M
125	1,600	1,200	0	2	0	*x*	*x*	*x*	*x*	*x*	35	*y*	M
126			0	2	0								
127	600	400	0	0	0	*x*	*x*	*x*	*x*	*x*	46	*y*	P
128	800	700	0	10	0	*x*	*x*	*x*	*x*	*x*	21	*y*	A
129	3,807	3,775	0	0	0	*x*	*x*	*x*	*x*	*x*	28	1.8	A
130	2,260	2,210				850	*y*	*y*					
131	3,550	3,500				1,800	*y*	*y*					
132	3,750	3,700				1,350	*y*	*y*					
133	4,120	4,100				1,520	*y*	*y*					
134													
135			35	2,690	2								

increased for several years and has not happened all in one year.

Although only three new gas wells were drilled, total gas production in the state increased approximately 20 per cent in 1935 over 1934 and is estimated to total about 19,900,000,000 cu. ft. This increase was caused by colder weather, better business conditions, and the development of bigger markets. There are still ample reserves of gas in sight for many years from present wells, and little necessity for more drilling.

Geophysical exploration work was fairly active in Wyoming in 1935 and several major companies from California and the Mid-Continent checked the possibilities and reserves of the state. It is expected that this

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1935		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
101			Tensleep	Pen	S	Por	40	A	0	Tensleep	3,903
102			Mowry	CreU	H	Fis	*x*	A	18	Embar	2,500
103	*x*	*x*	Sundance	Jur	S	Por	35	A	5	Granite	4,119
104	*y*	*y*	Frontier	CreU	S	Por	35	A	10	Chugwater	3,460
105			Muddy-Dakota	CreU	S	Por	60	A	2	Morrison	4,207
106			Dakota	CreU	S	Por	50	A	1	Lakota	3,930
107			Dakota	CreU	S	Por	110	A			
108			Sundance	Jur	S	Por	100	A			
109									11	Chugwater	3,390
110	*y*	*y*	First Wall Creek	CreU	S	Por	110	Af			
111	*y*	*y*	Second Wall Creek	CreU	S	Por	65	Af			
112	*y*	*y*	Lakota	CreL	S	Por	20	Af			
113	*y*	*y*	Sundance	Jur	S	Por	70	Af			
114	*y*	*y*	Tensleep	Pen	S	Por	190	Af			
115										Granite	5,400
116			Shannon	CreU	S	Por	75	MuP	41		
117			Embar	Per	L	Cav	25	A	2	Tensleep	2,486
118			Quealy	CreU	S	Por	40	A	16	Steele	6,931
119			Tensleep	Pen	S	Por	150	A	5	Tensleep	2,500
120			Embar	Per	L	Cav	40	A	0	Embar	2,514
121			Sundance	Jur	S	Por	25	A	8	Tensleep	2,705
122			Tensleep	Pen	S	Por	150	A	0	Amsden	4,255
123			Aspen	CreU	H	Fis	*x*	MC	65	Bear River	2,065
124	*y*	*y*	Wall Creek	CreU	S	Por	40	Af			
125			Steele	CreU	H	Fis	*x*	Af			
126									10	Frontier	3,140
127			Mowry	CreU	S	Por	50	A	95	Madison	4,165
128			Embar	Per	L	Cav	65	A	18	Tensleep	1,590
129			Embar	Per	L	Cav	35	A	4	Embar	3,807
130	*y*	*y*	Frontier	CreU	S	Por	50	A			
131	*y*	*y*	Dakota	CreU	S	Por	50	A			
132	*y*	*y*	Lakota	CreL	S	Por	40	A			
133	*y*	*y*	Sundance	Jur	S	Por	20	A			
134									4	Sundance	4,150
135									1,710		

year will be more active than 1935, but until new markets are developed any discoveries become reserves for the future and do not affect the immediate situation.

Petroleum Development in the Argentine in 1935

By Guillermo Hileman*

(New York Meeting, February, 1936)

In March the President approved the new oil bill, which became effective as Law No. 12161, providing among other things a contribution or tax on all producers varying from 8 to 12 per cent payable monthly. The new regulations, for chapter VI bearing on the tax feature, of this

Table 1.—*Oil and Gas Production in the Argentine Republic*

Line Number	Field, *Province or Territory*	Age, Years to End of 1935	Area Proved, Acres	
			Oil and Gas[a]	Total
	Comodoro Rivadavia, *Ter. Chubut*			
1	Zone A	28	10,809	10,809
2	Zone B	11	12,597	12,597
3	Zone C	19	3,161	3,161
4	Zone D	2		
	Plaza Huincul, *Ter. Neuquen*			
5	Zone 1	17	267	267
6	Zone 2	9	1,082	1,082
7	Zone 3	11	494	494
8	Zone 4	1		
	Dept. Oràn, *Prov. Salta*			
9	Zone Tartagal	9	494*y*	494
10	Zone San Pedro	7	247*y*	247
11	Zone Agua Blanca	9	62*y*	62
12	Cacheuta, *Prov. Mendoza*	4	*y*	
13	Tupungato, *Prov. Mendoza*	1	*y*	
14	El Sosneado, *Prov. Mendoza*	10	*y*	
15	Total			

[a] Footnotes to column headings and explanation of symbols are given on page 215.

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law were published in December and fix the percentage applicable between the above limits by specifying a weighted consideration of the following five factors: (1) productivity of the pool, (2) distance of the field from the principal center of distribution, (3) quality of crude produced, (4) average depth of the productive horizon, and (5) quantity of water and impurities in the crude produced.

The regulations fix an equal contribution or tax percentage on the gasoline extracted from the natural gas. However, if the natural gas is used for other industries that are not related to the exploitation of the pool or field, or if the gas is sold, the contribution or tax is fixed at 10 per cent of the value of the gas so used. The President for the purposes of this tax is empowered to fix the price of crude oil and natural gas periodically.

In May the President, acting under authority granted in the oil law, issued a decree placing all national territories in an oil reserve for a period of 10 years. This same decree also provides that no petitions for exploration permits filed by private parties or companies for obtaining exploitation concessions will be accepted. In the reserves thus estab-

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.			
	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935
1	82,566,748	4,526,592	5,161,391	15,133.3	7,638	263	10.7	130,973	15,541	11,450	37.5
2	21,896,163	5,155,259	5,038,025	13,216.0	1,738	52	79.6	14,969	4,415	4,833	14.5
3	13,435,393	1,162,153	1,192,722	3,409.8	4,250	326	12.8	7,316	1,236	1,347	3.9
4	23,752	9,297	14,286	34.0			34.0				
5	1,387,510	77,524	72,045	219.3	5,194	133	4.1	764	148	128	0.4
6	1,959,542	252,525	292,837	898.8	1,811	55	11.3	4,261	742	835	2.9
7	7,688,782	755,001	554,400	1,244.3	15,564	471	8.6	6,928	1,300	818	2.7
8	2,163		2,163	5.9			5.9				
9	2,761,788	357,970	265,029	758.0	5,590	169	7.4	3,853.7	424	639.6	1.2
10	4,808,517	1,438,900	1,447,952	4,021.4	19,467	671	223.4	5,605.4	1,943	1,508.3	7.1
11	543,815	236,605	197,745	505.0	8,771	439	101.0				
12	44,546	14,159	20,241	74.6			9.3				
13	18,097	1,887	16,209	37.8			6.3				
14	190,022	37,073	17,253	*y*			*y*				
15	137,326,838	14,024,945	14,292,298					174,670.1	25,749	21,558.9	

lished only the Government entity, the Dirección General de Yacimientos Petroliferos Fiscales, is authorized to carry on exploration and exploitation work.

The provinces of Jujuy and Salta annulled their reserve decrees, which had existed since 1924, and now admit requests for oil exploration permits subject to the provisions of the Federal Law No. 12161, which increased the exploration periods and established an exploration rental.

In 1935 the total production of the Republic showed an increase of 1.93 per cent over that of the previous year. This increase resulted from the new wells drilled by Yacimientos Petroliferos Fiscales in Comodoro Rivadavia along the coastal shelf of the Atlantic Ocean northeast of the old field in the Caletas Córdoba and Ali. Long piers with laterals were employed, to reach as many locations as possible and facilitate the work. This increase in production accounted for by the activities and successes of the Y.P.F. in Comodoro Rivadavia discounted the decline in production by the private companies in the entire Republic and resulted in the increase in total production for the year as indicated above.

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells							Average Depth, Ft.		Oil Production Methods at End of 1935					Pressure, Lb. per Sq. In.[e]		
		During 1935		At End of 1935						Number of Wells						Average at End of	
Line Number	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Misc.	Injection into Reservoir[d]	Initial	1934	1935
1	2,196	139	15	338	1,513	20	1,533	2,080	1,900	27	1,419	54	13	G 30	1,030	40	30
2	308	63	5	54	169	9	178	3,600	2,950	19	136		14	G 3	730	40	35
3	531	54	12	91	293	11	304	2,170	1,970		266		27		300	15	15
4	4	2			2	2	4	2,650	2,300		1		1			60	55
5	90	7	1	5	54	2	56	1,970	1,800	1	53			G 4	150	73	70
6	105	23	1	14	84	5	89	2,460	2,170	7	77				210	120	118
7	210	5	2	31	139	8	147	2,790	2,460		139			G 4	180	73	70
8	2	2			2		2	3,300	3,280				2		40		
9	139	9	3	16	102		102	1,770	1,470	1	60	31	10	G 1	60	60	60
10	35	7	0	15	15		15y	2,800	1,790	10	2	2	1	G 6	600	550	580
11	6	1			5		5	2,460	1,400	1	3		1				
12	22	2		3	7		7	2,000	1,996				7				
13	6	3	1		4		4	1,280	1,276				4				
14	8				8		8	552	547				8				
15	3,662	317	40	567	2,397	57	2,454			66	2,156	87	88				

The production of the Plaza Huincul field for the year was less than in 1934, notwithstanding the intensive development work in zone 2. Results obtained characterize this as a pool of rather limited importance but with structural characteristics quite distinct from those of other parts of the field. A new zone known as Bajo de los Baguales has been included in the statistics. The Y.P.F. is bending its efforts toward a thorough exploration of this zone in the hope that it will prove to be a structure of economic value.

One of the interesting features of the drilling activities in zone 2 was the introduction and successful operation of a modern rotary rig and equipment for the first time in this field. This rig has drilled practically the same number of wells as three standard cable tool rigs in the same period of time. Up to the present operators in this field have always employed cable tools and considered them as best adapted to the drilling requirements of the field.

In conclusion, the increase in drilling activities in Plaza Huincul was directed toward the discovery of new structures, which has presented difficulties because of the geological conditions. This is especially true

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1935: Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Depth of Hole, Ft.
1	24.0	20.6	22.0	0.18	M	854	0.51	Chubutiano & Glauconitico	Cre	SS	Por	29y	AF	119	Chubutiano	2,900
2	34.6	20.5	28.0	0.18	M	854	0.45	Chubutiano & Glauconitico	Cre	SS	Por	33y	AF	80	Chubutiano	4,980
3	21.3	19.0	20.0	0.18	M	850	0.12	Chubutiano & Glauconitico	Cre	SS	Por	13y	AF	93	Chubutiano	2,350
4	23.2	23.2	23.2	0.18	M	850	0.20	Chubutiano & Glauconitico	Cre	SS	Por	26y	AF	3	Chubutiano	3,150
5	34.4	33.4	34.0	0.20	M	905	1.54	Dogger	Jur M	S	Por	39y	MU AF	19	Dogger	1,970
6	34.2	33.0	33.8	0.20	M	905	1.12	Dogger	Jur M	S	Por	33y	MU AF	7	Dogger	2,610
7	34.2	33.0	33.8	0.20	M	905	1.11	Dogger	Jur M	S	Por	33y	MU AF	27	Triassic	3,420
8	34.0	33.0	33.6	0.20	M	905	y	Dogger	Jur M	S	Por	25y	MU AF	2	Triassic	3,750
9	45.3	43.9	44.0	0.10	P	917	0.84	Clay grit series	Per Carb	SS	Por	33y	A	30	Gondwana	4,200
10	46.0	44.7	45.0	0.10	P	917	0.84	Clay grit series	Per Carb	SS	Por	29y	A	6	Gondwana	3,010
11	23.2	22.8	23.0	0.10	P	917	0.30	Clay grit series	Per Carb	SS	Por	20y	A	3	Gondwana	4,080
12	31.2	17.0	28.0	0.14	P			Red beds	CreU	SS	Por	13y	AF	3	Triassic U	2,950
13	33 0	31.0	32.0	0.11	P			Calchaqueno	Ter	SS	Por	16y	AF	3	Cretaceous	1,620
14	13.0	11.0	13.0	12.0	A			Ranchhouse Conglomerate	Ter	SS	Por	13y	MIF	2		
15																

since it is a very extensive region which in proportion to the work done is still comparatively unexplored.

Production in the province of Salta also declined during 1935. The exploration wells outside the productive zones have resulted in practically no commercial production. The only discovery of interest is that of Rio Pescado, which is included in the same zone as Agua Blanca in the statistics. However, in passing it must be said that the number of exploration wells is on the increase and at present the Y.P.F., Standard Oil Co., Ultramar and Astra are very active in exploration drilling. In view of these activities it is hoped that 1936 will produce some interesting developments in that province.

Production in the province of Mendoza increased slightly over that of 1934. The pools in this province have a very limited production but

TABLE 2.—*Summary of Drilling Operations by Y.P.F. in the Argentine Republic*

	Field, *Territory or Province*	Well	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Initial Introduction Per Day		Pressure, Lb. per Sq. In.	Remarks
						Oil, Bbl.	Gas, Millions Cu. Ft.	Casing	
1	Comodoro Rivadavia, Chubut	T-2	5748	Miocene	Senonian	221		Variable	Zone B.
2	Comodoro Rivadavia, Chubut	S-95	3839	Miocene	Senonian	599		Variable	Zone B.
3	Comodoro Rivadavia, Chubut	C-14	3055	Miocene	Senonian	315		Variable	Zone B.
4	Comodoro Rivadavia, Chubut	C-15	2894	Miocene	Senonian	239		Variable	Zone B.
5	Comodoro Rivadavia, Chubut	L-21	5256	Miocene	Senonian			Variable	Dry. Abandoned.
6	Comodoro Rivadavia, Chubut	A-7	3780	Miocene	Senonian			Variable	Dry. Abandoned.
7	Las Heras, Santa Cruz	N-1	2953	Miocene	Senonian			Variable	Dry. Abandoned.
8	Plaza Huincul, Neuquen	No. 212	4255	Senonian	Triassic		0.72	1710	(18 liters gasoline per 1000 cu. m., zone D.)
9	Plaza Huincul, Neuquen	N.A.3	3983	Senonian	Dogger				Dry. Abandoned.
10	Plaza Huincul, Neuquen	N.B.6	3494	Senonian	Dogger				Dry. Abandoned.
11	Ñirihuau, Río Negro	No. 2	4780	Miocene	Tortonian				Dry. Abandoned.
12	San Cristóbal, Santa Fé	No. 1	3448	Tertiary	Lower Jurassic(?)				Suspended.
13	Lulunta, Mendoza	L-2	8124	Tertiary	Upper Triassic				Drilling in bituminous shales.
14	Malargüe, Mendoza	M-1	3687	Tertiary	Triassic(?)				Dry. Abandoned.
15	C. Durán, Salta	No. 5	4728	Tertiary	Tertiary				Suspended.
16	Río Pescado, Salta	No. 3	4065		Subandino	321			Deepening.
17	Saladillo, Jujuy	No. 1	6034		Subandino	252			Deepening.

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	106	12
Number of wells completed during 1935	330	2
Number of gas wells completed during 1935	2	2
Number of dry holes completed during 1935	47	19

those of Tupungato and Cacheuta, because of their proximity to the city of Mendoza and near-by centers of consumption, are being exploited by

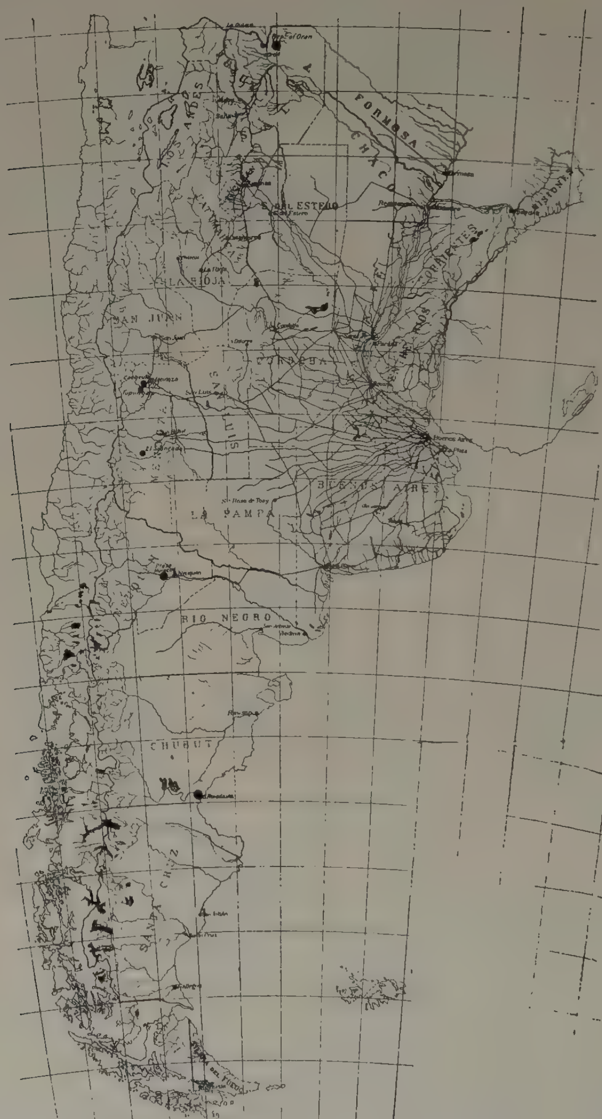

FIG. 1.—LOCATION OF OIL FIELDS IN THE ARGENTINE REPUBLIC.

the Y.P.F., which as a Government entity frequently sacrifices its profits in benefit to the region under exploration.

In the province of Jujuy the Y.P.F. drilled the discovery well near Saladillo de la Brea. Its initial production was 4 cu. m. (25 bbl.) per

day and at the end of December it had produced 385 cu. m. (2425 bbl.). On account of this discovery, and the lifting of the reserves, interest in exploration work has been revived in this province and other entities such as the Standard Oil Co. and the Ultramar Sociedad Anónima Petrolera Argentina are on the eve of initiating exploration work in the Departments of Santa Bárbara and Gobernador Ovejero.

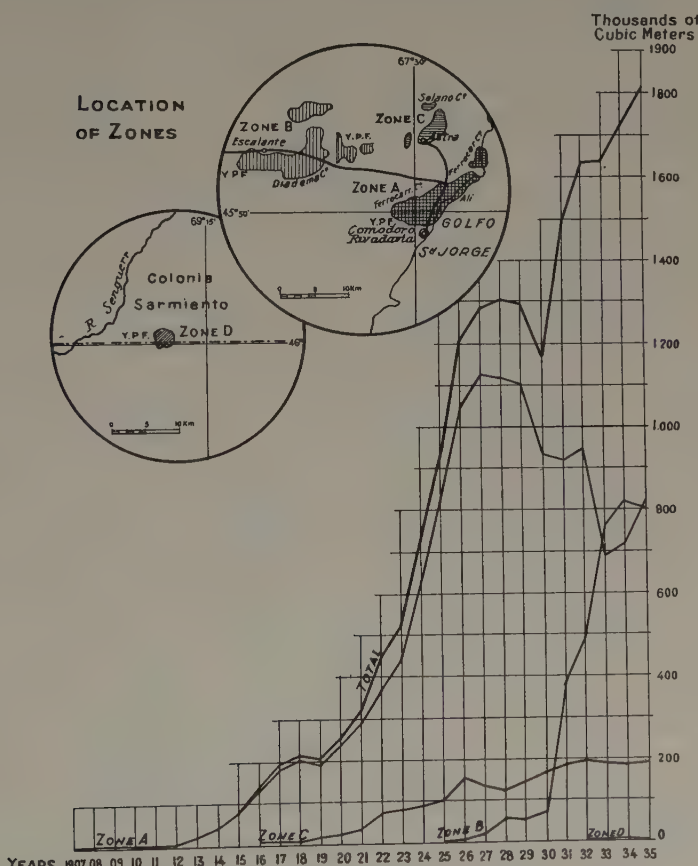

FIG. 2.—PRODUCTION BY ZONES, COMODORO RIVADAVIA FIELD, TERRITORY OF CHUBUT.

Among the progressive steps taken in Comodoro Rivadavia during the year was the utilization of the Schlumberger instrument in both old and drilling wells. Its use has enabled operators to study abandoned wells after removal of the casing and in some wells to locate new and higher horizons with productions up to 30 cu. m. (189 bbl.) per day. Where the instrument has been used in drilling wells, the results have been very satisfactory and with the present knowledge of the region the amount of coring has been reduced by using the Schlumberger.

As will be seen from the accompanying tables, by careful work and compilation it has been possible to divide the fields into separate producing zones. Each zone includes structures that have been well defined either by surface indications or by correlations on key beds that define the structural conditions at depth. This division makes it possible to determine the economic value of the various local pools or accumulations. Since these tables cover the entire Republic, some graphic illustrations are attached (Figs. 1 to 4) in order to give a concrete conception of the

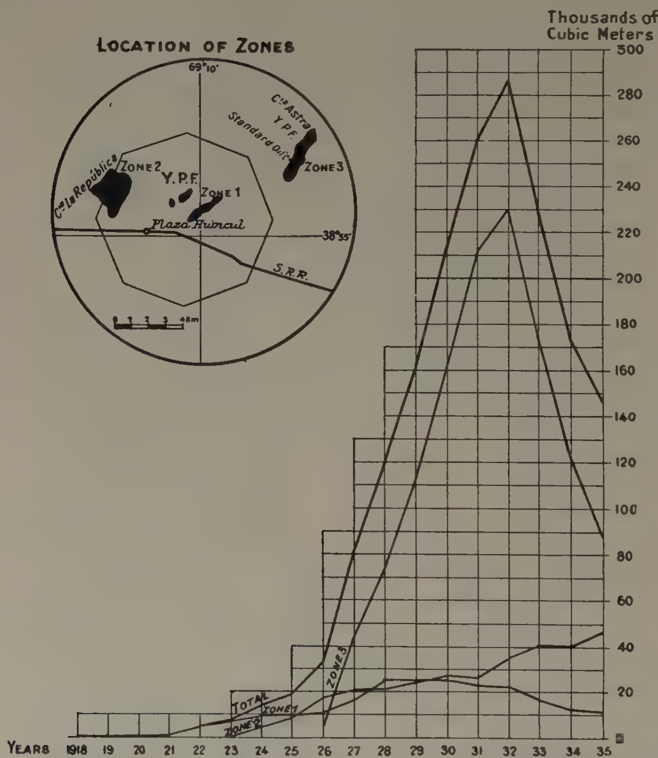

FIG. 3.—PRODUCTION BY ZONES, PLAZA HUINCUL FIELD, TERRITORY OF NEUQUÉN.

locations of the fields and how the industry has been initiated and developed in the country. These illustrations were published in the 1934 statistical bulletin of the Argentine Bureau of Mines covering crude-oil production, and for this reason the quantities are expressed in metric units.

The Bureau of Mines of the Argentine Republic has adopted the same form for the annual production statistics as that employed by the A.I.M.E. This innovation has been well received in professional circles of the oil industry.

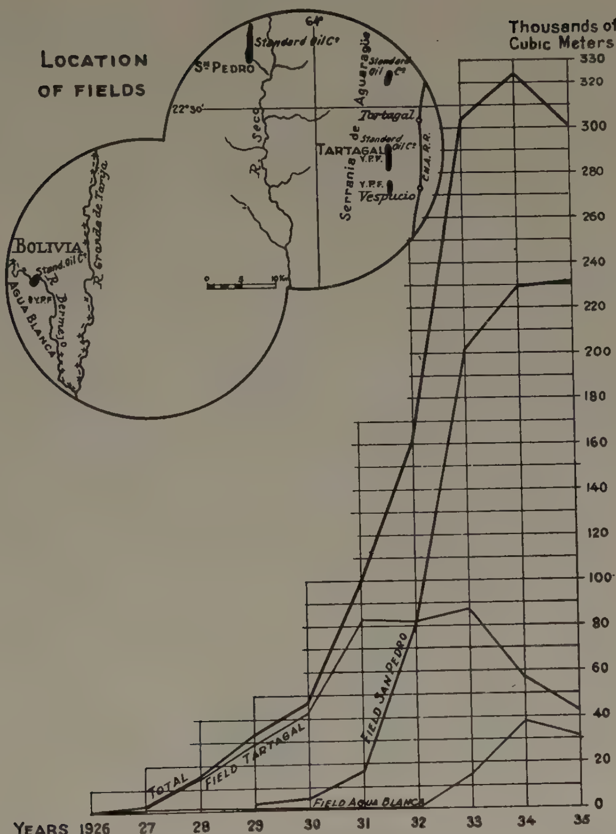

FIG. 4.—PRODUCTION BY FIELDS, PROVINCE OF SALTA, DEPARTMENT OF ORAN.

For the convenience and information of the reader, the companies operating in the various fields are listed below:

Territory of Chubut: Comodoro Rivadavia Field
- Yacimientos Petrolíferos Fiscales
- Diadema Argentina (Shell)
- Compañía Ferrocarrilera
- Compañía Astra
- Compañía Solano

Territory of Neuquen: Plaza Huincul Field
- Yacimientos Petrolíferos Fiscales
- Standard Oil Company of Argentina
- Compañía Astra

Province of Salta: Yacimientos Petrolíferos Fiscales
- Standard Oil Company of Argentine
- Compañía Astra
- Compañía Petrolífera del Norte
- Ultramar S.A. Petrolera Argentina

Province of Mendoza: Yacimientos Petrolíferos Fiscales
- Río Atuel Ltda.

Territory of Santa Cruz: Yacimientos Petrolíferos Fiscales.

Petroleum in Austria, Hungary and Czechoslovakia in 1935

By Walter M. Small,* Member A.I.M.E.

(New York Meeting, February, 1936)

Austria

Austria produced approximately 800 cisterns of 10,000 kg. each (56,000 bbls.) of crude oil of a 0.9428 sp. gr. during 1935. Of this Gösting II well near Zistersdorf, owned by the Erdölproduktions-Gesellschaft m.b.H., produced 86 per cent of the total, averaging a little over 1.8 cisterns, or about 125 bbl., per day. Gösting IVa of the same company was put in production early in December and produced a total of about 70 cisterns (4900 bbl.). Gösting IV was a failure, but a directional hole drilled from the same derrick produced Gösting IVa. Gösting I, a well owned jointly by the company above mentioned and the Raky-Danubia, was deepened late in the year and made about 2800 bbl. of oil at the rate of 70 bbl. per day.

Completions during the year were as follows: In the Gösting pool, Gösting IV and IVa, drilled with rotary tools, the latter producing from Sarmat at a depth of 934 meters (3065 ft.); Kronberg I, of European Gas & Electric Co. with cable tools in Flysch at a depth of 566 m. as a dry hole; in the Oberlaa gas pool, one cable-tool well of the same company at a depth of 266 m. as a dry hole and one Fauck-Haiek system well of the Vacuum Oil Co. at a depth of 483 m. as a dry hole; one rotary hole of the European Gas & Electric Co. at Enzersdorf a/d. Fischa plugged and abandoned in Sarmat after a blow out and gas eruption at a depth of 699.5 meters.

The status of drilling wells at close of the year is as follows: In the Gösting pool, Erdöl Bohr- und Verwertungs G.m.b.H., north of the producing area, was drilling with rotary at 990 m., Raky-Danubia is rigged up to deepen the old Windisch-Baumgarten hole, Rohoel-Gewinnungs A.G. (Vacuum-Shell combination) rigging up rotary south of the production, and Steinberg-Naphta G.m.b.H. (Musil) was deepened with light rotary to 830 m.; at Enzersdorf a/d. Fischa, the European Gas & Electric Co. E-2 rotary-drilled hole stood at 1533 m. in Miocene waiting for cement to set.

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* European Gas & Electric Co., Vienna, Austria.

The gas wells of the European Gas & Electric Co. at Oberlaa were shut in early in 1935 on account of water encroachment. During the year 2,900,000 cu. m. (10,239,900,000 cu. ft.) of gas was produced.

Some 4000 to 5000 m. of drilling are planned for the year 1936 by the companies operating in the Vienna Basin but plans for development elsewhere in Austria have not been announced.

Hungary

There were no producing oil or gas fields in Hungary in 1935. The Government deepened its Tard well near Bogács from 967 m. to 1814 m., with Fauck rig. It was bottomed as a dry hole in Triassic. The Government also drilled Oerszentmiklos III, some 26 km. northeast of Budapest, to a depth of 890 m. with a Fauck machine. It was finished as a failure in Eocene. The European Gas & Electric Co. completed Mihalyi I with rotary tools into crystalline rocks at a depth of 1603 m. A strong flow of CO_2 gas was developed and the well closed. The same company commenced and drilled its Görgeteg I with rotary tools to a depth of 1086 m. In all, three or four wells are known to be planned for 1936.

Czechoslovakia

In Gbely (Egbell) there were produced 1200 cisterns (December production being estimated), of 10,000 kg., of 0.935 sp. gr. oil and a very small amount of gas used for engines. This pool is operated by the Government. Thirty new shallow wells were drilled, making a total of 4800 m. of hole; 29 of these were classed as productive and one as a dry hole.

In Hodonin (Göding), the Apollo produced 832 cisterns of 10,000 kg. of 0.91 sp. gr. oil and an average of 27,000 cu. m. gas monthly used on the property. The Apollo's drilling was as follows:

	Meters
5 producing wells and one being drilled	2,713
4 old wells deepened a total of	600
1 small gas well near Hodonin	449
1 small gas well near Hodonin	325
Total	4,087

The Government is drilling on a wildcat at Ratiskovice at a depth of 320 m. and deepened its Josina wildcat in the Carpathian region to a depth of 960 m. The Bata Shoe Interests drilled a hole at Rohatec to 178 m. Another private company is reported to be about ready to abandon its Auspitz well at 580 meters.

Petroleum Prospecting Operations in Australia and New Guinea during 1935

By W. G. Woolnough*

(New York Meeting, February 1936)

There has been no noteworthy increase in production during 1935; but, on the other hand, there have been ample manifestations of a considerable increase in interest and activity in connection with petroleum prospecting.

The Lakes Entrance field, in the State of Victoria, on the coast some 120 miles east of Melbourne, remains the only actual producer; and this production, consisting of lubricating stock devoid of light fractions, is very small in amount. Arrangements have been completed under which a series of "scout bores" for structure testing in the region of Lakes Entrance will be sunk by the Government of the State of Victoria, assisted by a subsidy from the Federal Government.

Prospecting

In the State of New South Wales, brilliant geological research in very difficult country, carried out by geologists of Oil Search Ltd., has revealed several previously unsuspected domal structures in the Sydney-Newcastle coal basin. These have been mapped in detail, and a test well is being sunk at Kulnura, 10 miles west of Wyong and 40 miles north of Sydney. At the date of writing this well has reached a depth of 1250 ft., 10-in. casing having been set at 1248 feet. Superficial formations consist of the Hawkesbury sandstone and Narrabeen beds of the Hawkesbury system (fresh-water Triassic). It is anticipated that the upper coal measures of the Kamilaroi (Permo-Carboniferous) will be entered almost immediately. The objectives of the drilling are the upper and lower marine beds of the Kamilaroi system, which are regarded as promising as potential source—and reservoir—beds for oil.

At Mulgoa, 30 miles west of Sydney, a bore is being sunk by the same company, Oil Search Ltd., to test for natural gas on a well defined structure located by the company's geologists. Noteworthy flows of gas have been encountered, but nothing approaching a commercial supply has been struck. It is considered probable that the gas has been derived

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from the upper Kamilaroi coal measures, which have been pierced. The bore is being continued.

Considerable excitement was caused by the development of a fairly strong gas flow in a well sunk at Balmain in the heart of the City of Sydney. The well was sunk from the bottom of a coal shaft that is 3000 ft. deep; and the gas was struck, under heavy pressure, at a depth of 4087 ft. from the surface. Analyses of the gas, taken at different times, show curious and unexplained anomalies. Some analyses indicate almost pure methane, while others give notable amounts of heavier hydrocarbons.

At first the pressures were considerable; but later tests reveal great falling off in this respect. It is necessary, therefore, to exercise great caution in any forecast in regard to this occurrence. While it *may* be the beginning of a gas industry which could not fail to be extremely important if sufficiently extensive, seeing that the gas has been tapped in the heart of the largest city in Australia, the area is synclinal in structure, and nothing is known to suggest that conditions are suitable for gas storage on an extensive scale. There is a possibility that the gas encountered may be merely a pocket, produced by destructive distillation of the coal seams occurring in the upper portion of the Kamilaroi system. Numerous basaltic dikes of Tertiary age intersect the coal measures in this part of the basin, and have converted the coal into coke, sometimes over considerable areas. Exploration is being continued.

In the State of Queensland, a well sunk by Oil Search Ltd. on a small, but clearly defined structure at Warooby Creek, near Roma and about 300 miles west of Brisbane, yielded strong traces of oil, and noteworthy amounts of gas containing about 1¾ pints of gasoline per 1000 cu. ft. Owing to activity by the company in other fields, this project has been suspended for the time and the well sealed down.

Several other larger and more promising structures have been met with and mapped by the same company in the region somewhat to the north of Roma, and attention is being concentrated on these at present. A "scout bore" to test the geological column was sunk at Arcadia, 80 miles north of Roma, on one of these structures, and proved the presence of both gas and oil in small quantities. Still more important, it indicated that the Kamilaroi sediments underlay the superficial freshwater Mesozoic formations, and were the source rocks of the hydrocarbons. This extends and confirms the geologic mapping results in adjacent areas. Only shortage of funds is delaying the testing of this promising dome. A test well is being sunk at Hutton Creek, 60 miles north of Roma, on another of the domes. This well has reached a depth of about 1500 feet.

In the State of Western Australia, the Freney Kimberley Co. has continued its operations in the Fitzroy River Valley in the Kimberley Division of that state, assisted by funds granted by the Federal and State

Governments. Dr. Arthur Wade has been engaged for a considerable time in carrying out this survey, and his report on the region is expected shortly.

Oil Search Ltd. has carried out very extensive geological investigations, partly based on the results of aerial reconnaissance, in the northwest division of Western Australia. The results of the earlier phases have been described by the Chief Geologist to the company, Mr. D. Dale Condit[1]. A remarkably complete stratigraphic section, extending from Cretaceous to Miocene, has been revealed in this survey, as a result of the paleontological investigations of the Federal Paleontologist, Mr. Frederic Chapman, and this work is being continued by his successor, Miss Crespin. This is the first occasion on which true Eocene formations have been encountered on the mainland of Australia.

Promising domal features have been located, and work is being energetically prosecuted.

Commonwealth Oil Refineries Ltd., a company of which the shares are held jointly by the Commonwealth Government and the Anglo-Iranian Co., is actively entering the field of search. The Chairman of Directors of the Anglo-Iranian Co. visited Australia last year, and arranged to assist in the search by sending senior geologists to participate. The Senior Geologist of the company, Dr. G. M. Lees, and Dr. K. Washington Gray, Senior Geologist in Iran, carried out a preliminary aerial reconnaissance of the whole of the likely areas in Australia, accompanied by the Commonwealth Geological Adviser. Dr. Gray has remained in Australia in order to carry out more detailed investigations. By arrangement with Oil Search Ltd., the areas in the northwest division of Western Australia were investigated jointly by the geologists of the two companies. In addition, other areas will be examined by Dr. Gray independently.

The Prime Minister of the Commonwealth has recently announced the intention of his Government to take an active part in the search for oil within the Commonwealth. All indications, therefore, point to a very active prospecting campaign during the next few years.

In the Territories

In the Mandated Territory of New Guinea, Oil Search Ltd. has continued the geological survey that has been in progress for a number of years. Under phenomenally difficult climatic and topographic conditions, this work has reached a stage where the selection of drilling sites can be entered upon.

In the Territory of Papua, the search for oil has been in abeyance for a considerable time, but there is evidence that it will be renewed actively during the current year.

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[1] *Econ. Geol.* (1935) **30**, 860–878.

Legislation

It must be remembered that, throughout Australia and its Territories, petroleum is vested in the Crown, except for a few small areas of land, alienated in the early days of settlement of the country, and held under land titles differing from those universally adopted at present. Hence petroleum legislation differs markedly from that in countries where the surface owner possesses mineral rights.

New legislation in regard to petroleum has been passed in the State of Victoria, giving the owners of mineral rights within what are termed "prior lands" until 1940 to exercise their rights. After that date all oil will revert to the Crown, and the process of search will be simplified in many ways.

New and very liberal ordinances governing petroleum have been passed simultaneously in the Territories of Papua and New Guinea, and it is hoped that petroleum prospecting will receive considerable impetus as a result.

New legislation of a similar type is envisaged in Western Australia.

Petroleum Development in Bahrein Island and Saudi Arabia during 1935

By J. O. Nomland*

(New York Meeting, February, 1936)

The work of The Bahrein Petroleum Company, Ltd., on Bahrein Island consisted mainly in continuing development work and prospecting previously reported. The exploratory work, however, has been greatly minimized and new wells are being drilled, chiefly for the development of larger production; 20 wells had been completed by the end of 1935 and 8 were being drilled. In addition to what has been referred to as the "main pay," two deeper productive horizons have been discovered, which apparently will greatly increase the potential of the field although the areal extent of this lower production has not yet been determined. The proven acreage of the "main pay" is more than 12,500 acres. Current production (principally from the upper horizons) is about 13,400 bbl. a day. The construction of a 10,000-bbl.-a-day refinery has begun and is to be in operation by July, 1936. It is expected that the capacity will be considerably increased at a later date. The construction of office buildings and a permanent camp has been almost completed.

In Saudi Arabia the California Arabian Standard Oil Co., a wholly owned subsidiary of the Standard Oil Company of California, spudded in a well in April, 1935, near the village of Dammam, on the Persian Gulf coast of Al Hasa. Although several important showings of high-gravity oil and considerable gas have been found, the well is not yet considered a commercial producer. Dammam well No. 2 has been started farther south on the same structure. A great deal of reconnaissance and some detailed geological work has been completed during the last three field seasons. In order to overcome difficulties of transportation over the desert sand, unusual methods have been used. The parties penetrating the interior by the use of automobiles and trucks have been supplied with gasoline and provisions by caravans of camels. Mail and supplies of lighter weight urgently needed have been carried to the field men by an airplane operated by the geological division of the company. Each party has been supplied with a radio receiving and transmitting set to keep in contact with the airplane as well as with geological headquarters at Jubail on the coast of Al Hasa.

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* Standard Oil Company of California, San Francisco, Calif.

Petroleum Development in Bolivia in 1935

By Jorge Muñoz Reyes*

(New York Meeting, February, 1936)

There was no development work in Bolivia during the year 1935, and oil was produced only to meet the needs of the army and of the local market. The refineries in the districts of Camiri and Sanandita treated 25,978,737 liters (163,388 bbl.) of crude oil, which yielded 4058 bbl. of aviation gasoline (Camiri only), 7381 bbl. of gasoline, 718 bbl. of kerosene (Camiri only) and 83,105 bbl. of fuel oil.

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* Direccion General de Minas y Petroleo, La Paz, Bolivia.

Oil and Gas Developments in Canada during 1935*

By G. S. Hume†

(New York Meeting, February, 1936)

Petroleum is produced in Canada in the provinces of New Brunswick, Ontario and Alberta and in the Northwest Territories. The total production, however, is relatively small in comparison with the consumption, the value of imports exceeding 40 million dollars a year. Production figures are given in Tables 1 and 2.

Table 1.—*Production of Petroleum in Canada*
Barrels of 35 Imperial Gals. = 42 U.S. Gallons

	1934	1935[a]
Alberta	1,260,000	1,252,700
Ontario	141,385	161,600
New Brunswick	11,545	10,900
Northwest Territories	4,438	4,000
Total	1,417,368	1,429,200

[a] Production estimated by Mining, Metallurgical and Chemical Branch, Dominion Bureau of Statistics, Ottawa.

Table 2.—*Production of Natural Gas in Canada*
Thousands of Cubic Feet

	1934	1935
Saskatchewan	13,781[a]	75,200
Alberta	14,000,000	14,933,300
Manitoba	600	600
Ontario	7,327,474	6,950,000
New Brunswick	607,000	608,600
Total	21,948,855	22,567,700

[a] Part year production from Lloydminster field.

In Turner Valley, still the largest producing gas and oil field in Canada, five wells were completed during the year. The largest of these

* Published with the permission of the Director, Bureau of Economic Geology, Department of Mines, Ottawa, Ont. Manuscript received at the office of the Institute Feb. 8, 1936.

† Bureau of Economic Geology, Department of Mines, Ottawa, Ont.

was Royalite No. 26, in the north end of the field, which had an initial flow of 25,000 M. cu. ft. of gas and a production of 250 bbl. of naphtha at a back-pressure on the well of 1000 lb. At the end of the year seven wells were drilling in Turner Valley. A considerable amount of gas continues to be burnt after the extraction of naphtha from it. This amount is less in the winter because gas from this field is used to supply Calgary and adjoining towns.

East of Turner Valley, in the Alberta syncline, the Ranchmen's well, which obtained some oil in the lower part of the Upper Cretaceous, is still being deepened with encouraging shows. At the end of the year the depth of the well is reported at 6655 ft. In southern Alberta, Terminal No. 1 well, to the north of the Cut Bank field of the United States, has obtained encouraging shows of oil in the Ellis (Jurassic) formation above the Paleozoic limestone. At the end of the year the well had not been completed into the limestone but there is hope that it may open a new producing field. In north central Alberta, a well was drilled for gas at Vegreville, east of Edmonton. This well gave a show of heavy oil and salt water at 2120 ft., but was abandoned. The Viking gas area, southeast of Vegreville, continues to be the largest producing gas field in this part of the Province.

In Saskatchewan, at Lloydminster, just east of Alberta, two new gas wells were drilled in a field opened up in 1934. One of these wells is reported to have an open flow of 42,600 M cu. ft. and 410 lb. closed pressure and the other has a flow of 8178 M cu. ft. and 440 lb. pressure. Both wells are capped at the present time. Gas for the town of Lloydminster, which has a population of about 1000 people, is supplied by the discovery well, which had an initial flow of 16,750 M cu. ft. and a closed pressure of 565 lb. The gas from the discovery well occurs at a horizon within Lower Cretaceous strata whereas the gas in the other two wells occurs at the contact of Upper and Lower Cretaceous beds. The lower horizon has not been tested in either of these two wells. The eastern limit of the field may have been reached by a nonproducing well drilled one mile east of the discovery well. The western limit has not been determined.

In the Ontario fields of the southwestern peninsula of Ontario, between lakes Huron and Ontario, marked success has prevailed during the year in drilling new gas wells. Probably between 125 and 150 wells, most of them relatively shallow, have been completed. A few of these produced oil and a few were dry holes, but by far the greater proportion are gas wells with moderate flows of several hundred thousand up to more than fifteen million cubic feet per day. The largest wells were drilled in Raleigh township, Kent County in the d'Clute field. Five wells with a flow of 5 to 15 million cubic feet were drilled in this field in 1935, production being secured from Silurian strata at a depth of about 1550 ft. In the Dover field of Kent County, several new wells yielding 3 to 5 million

cubic feet and a few smaller ones were completed. The depth of these wells is 3000 to 3200 ft. One hole 3731 ft. deep was dry. Production is secured from the Trenton limestone. Success has also attended the extension of the gas area south of Tillsonburg in Bayham township, Elgin County and Middleton township, Norfolk County. These wells yield 300,000 to 500,000 ft. but some have yielded up to one million cubic feet. The depth of the wells is between 1250 and 1350 ft. A great many wells were drilled in Haldimand County during the year; most of them are less than 100,000 cu. ft. but a few larger ones occur. The depth varies in the different townships of the county from 600 to 1000 ft. A new development in this part of Ontario during 1935 was the building of a pipe line to supply the city of London with gas. The gas is brought down from the Dawn field in Lambton county, where a considerable reserve is available.

No new gas or oil developments have occurred in New Brunswick during 1935. Normal production has been maintained from the Stony Creek gas and oil field near Moncton, with a slight but insignificant increase in the gas and a small decrease in the oil production. In the Northwest Territories the Imperial Oil Co. operates a small refinery at two oil wells north of Fort Norman. The oil is used mainly for transportation purposes and for fuel and power at the mining camps on Great Bear Lake.

Petroleum Development in Colombia during 1935

By O. C. Wheeler,* Member A.I.M.E.

(New York Meeting, February, 1936)

In past years the exploration of the oil possibilities of Colombia has been confined to parts of three distinct physiographic provinces; namely, the coastal plains area near the Caribbean Sea, the Magdalena Valley and the upper reaches of the Maracaibo Basin near the Venezuelan border. During 1935, little exploratory work and no drilling was carried on on the coast, but there was considerable activity in the other two areas. In the Magdalena Valley, the Tropical Oil Co. continued its producing and development operations on the De Mares Concession. The Socony-Vacuum exercised the option it acquired in 1934 on Sr. Luciano Restrepo's concession adjacent to the Tropical property and north of the Sogamoso River. No wells have been started on the Socony's lands although, according to the terms of the lease, drilling must be started within the next two years. West of the Carare River and adjacent to the Tropical's southwestern boundary, the Sociedad Nacional del Carare denounced the lands formerly held by the Union Colombiana, whose lease automatically lapsed during the year owing to the company's failure to comply with its drilling obligations. In the same area, the concessions held by Callejas et al. and the Société Européene des Pétroles are also understood to have lapsed for the same reason. Holdings of other interests in the Magdalena Valley were inactive during the year.

Near the upper part of the Maracaibo Basin, the Gulf, through its subsidiary the Colombian Petroleum Co., continued active exploration and development on its Barco concession.

Colombian Petroleum Co.—The following information and that presented in the accompanying tables relating to the activities of the Colombian Petroleum Co. was supplied through the courtesy of Mr. E. S. Bleecker, chief geologist of that company.

Four wells were completed during the year on the north Petrolea dome, where an attempt is being made to define the limits of the field. On the south end of the Petrolea anticline, one well, Petrolea No. 3, which might be classed as a wildcat, encountered a heavy flow of salt water immediately below the oil zone and had to be abandoned. A second location has been made 1½ miles south of No. 3 and somewhat higher on

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* Geologist, Tropical Oil Co., Toronto, Canada.

the structure, which will be drilled as soon as the railroad can be extended to the well site.

Oro No. 2, the company's initial test on the Rio de Oro anticline, was spudded in in April and on Dec. 31 was drilling at about 5000 ft. in

TABLE 1.—*Oil and Gas Production in Colombia in* 1935[1]

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Area Proved, Acres: Total
1	Infantas, *Santander*	17	x	x
2	La Cira, *Santander*	9	x	x
3	Petrolea, *Santander del Norte*	3	x	x
4	Rio de Oro, *Santander del Norte*	15	x	x
5	Las Monas, *Santander*	8	x	x

[1] For details on similar operations in previous years in other parts of Colombia see *Trans.* A.I.M.E. (1934) **107**; (1935) **114**.

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.			
	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935
1	99,890,146	9,025,665	6,937,962	19,550	x	x		103,247,000[2]	15,822,778	12,000,000[2]	y
2	67,177,392	8,315,059	10,659,692	33,215	x	x		61,350,000[2]	9,048,972	11,000,000[2]	y
3		y	y	y	x	x	y	x	x	x	
4	x	0	0	0	x	x	0	x	x	x	
5	y	y	y	y	x	x	y	x	x	x	

[b] Footnotes to table heads and explanation of symbols are given on page 215. [2] Approximate estimate.

the Upper Cretaceous shales. This well will be drilled to the Lower Cretaceous formations that are productive at Petrolea. During the latter part of the year the tractor road was extended from Oro No. 2 to the location for Oro No. 3, which is approximately 4200 ft. northwest of No. 2.

Tropical Oil Co.—The Tropical completed 40 wells in the Infantas and La Cira fields during 1935, all of which were producers. These two fields supplied the entire output of the property, amounting to 17,597,654 bbl., of which 362,991 bbl. was petroleum condensate added to crude.

The proven area at La Cira was extended by the completion of several producers on the flank of the structure. At Infantas, a small extension was made through the completion of a light producer in a previously untested fault block on the east side of the structure.

A caterpillar road approximately 40 km. long was completed from the San Vicente highway near Albania to the Tropical's Putana concession, where a wildcat well, Lisama No. 1, was started during the latter part of the year. At the end of the year, this well was drilling at 2491 ft. Another exploratory well was started in the Infantas field, where a test of deeper horizons is to be made, and had reached a depth of 2778 ft. at the end of the year.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935: Number of Wells: Flowing	Number of Wells: Pumping	Injection into Reservoir[d]	Pressure Lb. per Sq. In.[e]: Initial	At End of: 1934	At End of: 1935
1	452	1	0	} 274	} 459	} 459	1,000–2,600	400–2,200	} 42	} 417	33	x	x	x
2	283	40	0				600–3,650	400–3,350			15	950–1,450	x	600–1,400
3	7	3	2				1,527	y	y	0		x	x	x
4	1[3]	0	0				900	x	0	0		x	x	x
5	9	0	0						Shut in			x	x	x

[3] Abandoned.

Line Number	Character of Oil Approx. Average during 1935: Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas Approx. Average during 1935: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Depth of Hole, Ft.
1	36	23	26.5	0.90	A	1,050		A, B and C zones	Oli, Eoc.	S	15–22	50–200	AF	12	Cre	3,790
2	27	20	24.5	0.90	A	1,050		A, B and C zones	Oli, Eoc	S	15–25	50–175	AF	1	Cre	3,536
3	47	40		0.2	P	x		1, 2 and 3 zones	CreL	L	x	x	A	1	CreL	3,007
4	x	x		x	A	x		y	Eoc	S	x	x	A	1	CreU	5,000
5	y	y		y	A	x		y	Eoc Cre	S	y	y	A	4	CreU	5,434

TABLE 2.—*Summary of Drilling Operations in Colombia*

Important Wildcats Drilled in 1935

	Department	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day: Oil, U.S. Bbl.	Initial Production per Day: Gas, Millions Cu. Ft.	Remarks
1	Santander del Norte...	1,329	Cretaceous	Lower Cretaceous	Colombian Petroleum Co.	347		Abandoned because of water trouble

	In Proven Fields	Wildcats
Number of Wells Drilling Dec. 31, 1935	6	3[1]
Number of Oil Wells Completed during 1935	43	
Number of Gas Wells Completed during 1935	0	
Number of Dry Holes Completed during 1935	2[2]	

[1] Colombian Pet. Company's Oro No. 2, Rio de Oro structure, Santander del Norte.
Tropical Oil Company's, Lisama No. 1, Lisama structure, Santander.
Tropical Oil Company's, U-1, Infantas structure, Santander.

[2] One abandoned because of water trouble; one dry.

Oil and Gas in Egypt, 1935

By H. Sadek*

The accompanying table shows the available data pertaining to the Hurghada field, the major oil and gas field in Egypt. Operations in Abu Durba, a small field, amounted to almost nothing in 1935.

Table 1.—*Oil and Gas in Egypt,* 1935

Line Number	Field	Age, Years to End of 1935	Area Proved, Acres	Total Oil Production, Bbl.[1]		
			Total	To End of 1935	During 1934	During 1935
1	Hurghada	22	1,050	27,845,920	1,474,804	1,231,274

Line Number	Average Oil Production, Bbl.[1]			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells					
	Per Acre to End of 1935	Per Acre-foot to End of 1935	Per Well Daily during Oct., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935		At End of 1935		
									Completed	Abandoned	Total Producing	Abandoned	Dry
1	26,517	217	46	3,693	351	285	0.85	91	1	2	74	17	17

Line Number	Average Depth, Ft.[2]		Oil Production Methods at End of 1935 Number of Wells	Character of Oil, Approx. Average during 1935					Character of Gas Approx. Average during 1935		Producing Rock		
	Bottoms of Productive Wells	To Top of Productive Zone	Pumping	Gravity at 60° F.			Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]
				Maximum	Minimum	Weighted Average							
1	1,720	1,598	74			0.900		M		6.5	Main rock is Nubian sandstone	Cre	S

[1] The figures given by the author were in tons. Conversion factor of 6.98, based on 0.900 sp. gr., was used to obtain the number of barrels.—Ed.

[2] Although the thickness of the producing zone is 122 ft., all the sand in the zone is not productive of oil.

[f] Footnotes to table heads and explanation of symbols are given on p. 215.

* Controller, Department of Mines and Quarries, Dawâwin P.O., Egypt.

Petroleum Research in France and in the French Possessions during 1935

By H. de Cizancourt*

(New York Meeting, February, 1936)

There is no new outstanding fact to be noted concerning the development of petroleum production and research in France and her possessions during 1935.

France.—Pechelbronn remains the only important producing field in France. The total output has reached 538,921 bbl., showing a small decrease on last year's figures. Out of this, 302,737 bbl. was extracted by drilling and 236,184 bbl. (44 per cent) was obtained by means of shafts and galleries.

Exploration of deeper formations was still in progress, and resulted in the discovery of a new Middle Triassic (Muschel-Kalk) producing horizon.

In the vicinity of Hirtzbach (South Alsace) shallow exploration tests (500 ft.) were drilled by the Société de Pechelbronn, oil indications being found in the Tertiary. Two more important wells are now drilling in deeper horizons.

The Chantenay well (Nièvre) was finished in August, 1935, at a depth of 3544 ft.[1] A test is under progress in Savoie. South of Gabian, at Pezenas, the erection of a rig is nearly completed.

Table 1.—*Oil and Gas Production in France and French Possessions*

Line Number	Field	Age, Years to End of 1935	Area Proved, Acres	
			Oil	Total
1	Pechelbronn, *Bas-Rhin, France*	200	71,400	71,400
2	Gabian, *Herault, France*	11	14	
3	Tliouanet, *Algeria*	24	30	30

[b] Footnotes to column headings and explanation of symbols are given on page 215.

Manuscript received at the office of the Institute March 24, 1936.

* Compagnie Française des Petroles, Paris, France.

[1] This well was erroneously reported as "completed in 1934" in last year's note.

TABLE 1.—*(Continued)*

Line Number	Total Oil Production, Bbl. To End of 1935	Total Oil Production, Bbl. During 1934	Total Oil Production, Bbl. During 1935	Average Oil Production, Bbl. Per Acre to End of 1935[b]	Average Oil Production, Bbl. Per Well Daily during Nov., 1935	Number of Oil and/or Gas Wells: Completed to End of 1935	Number of Oil and/or Gas Wells: During 1935 Completed	Number of Oil and/or Gas Wells: At End of 1935 Producing Oil Only	Number of Oil and/or Gas Wells: At End of 1935 Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone
1	14,463,459	553,575	538,921	200	1.68	±3,800	104	641	641	1,355	498
2	155,121	2,955	3,233	11,100		14		5	5	532	311
3	193,780	2,962	2,663			± 100		6	6		

Line Number	Oil Production Methods at End of 1935: Number of Wells: Flowing	Pumping	Air-lift	Misc.	Injection into Reservoir[d]	Character of Oil Approx. Average during 1935: Gravity A.P.I. at 60° F. Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas Approx. Average during 1935: B.t.u. per Cu. Ft.	Gals. Gaso. per M. Cu. Ft.	Producing Rock: Age[g]	Character[h]	Structure[i]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Depth of Hole, Ft.	Reference to Text[k]
1	1	640		By shafts		17.4	37.6	29.1	0.04	PM			Olig Jur Tri	S S D	AF MF	60%	Middle Tri	3,051	A
2		5				34.8	37	35.7		P			Tri	D	A		Paleozoic (Silurian)	2,446	
3		4	2			39	47.6			P			Mio	A			Cretaceous		A

TABLE 2.—*Summary of Drilling Operations in France and French Colonies*

Important Wildcats Drilled in 1935

	Country	Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
1	France	Hirtzbach (South Alsace)		Oligocene	Jurassic	Pechelbronn S.A.	Small wells to 500 ft. dry
		Chantenay (Nièvre)	3544	Permian	Permian		
2	Morocco	Dj. Tselfot	1935	Jurassic	Jurassic	Ste. Cherifienne des Petroles	Dry
		Dj. Tselfot	2083	Jurassic	Jurassic	Ste. Cherifienne des Petroles	Dry
		Dj.Tselfot	2109	Jurassic	Jurassic	Ste. Cherifienne des Petroles	Dry
		Petitjean	3395	Miocene	Jurassic	Ste. Cherifienne des Petroles	Dry
		Rharb	6583	Miocene	Miocene	Ste. Cherifienne des Petroles	Dry
3	Tunisia	Slouguia	1469	Miocene	Miocene	Syndicat d'Etudes et Recherches	Dry
4	Madagascar	Andrafiavelo	1512	Cretaceous	Jurassic	Syndicat d'Etudes et Recherches	Dry

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	33	13
Number of oil wells completed during 1935	48	
Number of gas wells completed during 1935		
Number of dry holes completed during 1935	61	14

Algeria.—Production in the Tliouanet field is gradually decreasing. There were no fresh drilling operations during the past year.

Morocco.—There was much exploration work in Morocco during the year 1935. Out of 17 completed wells, with a total footage of 19,735 ft., 11 were drilled to a depth of more than 1500 ft. Five wells were drilling at the end of the year. Oil indications were found in most of these wells but there has been no production as yet.

Tunisia.—Slouguia No. 4 has been completed. Drilling was in progress in three wells in December, 1935.

Madagascar.—One well completed at Andrafiavelo (Andrafiavelo No. 2). The erection of a rig was in progress at the end of the year in the vicinity of Folakara.

Afrique Equatoriale.—Only shallow geological exploration wells were completed during 1935. A deeper well was drilling at the end of the year at Madiela.

Petroleum Development in Germany during 1935

By Walter Kauenhowen*

(New York Meeting, February, 1936)

Germany's crude oil production during 1935 totaled 3,007,711 bbl., an increase of 36.6 per cent over the 2,202,214 bbl. produced in 1934. The Nienhagen-Haenigsen field furnished 77 per cent of the total 1935 production. Cumulative production figures for Germany's two most important oil fields, Wietze and Nienhagen, show that during the period from 1872 to the close of 1935 the Wietze field produced 13,325,536 bbl. and the Nienhagen field 9,340,870 bbl. Table 1 gives statistics of German production since 1928, arranged both by fields and by oil provinces. Fig. 1 demonstrates the production of the various German fields since 1890.

New Fields Discovered

During 1935 five new fields came into production. The first of these, the Moelme-Hoheneggelsen field near Hanover, was opened up in April. This region has been sporadically drilled for oil since 1882, but not until 1935 was production on a commercial scale obtained. The oil comes from Mesozoic sandstones on the flanks of a shallow salt plug. Also during April, oil was found in commercial quantities in the Rhine valley at Forst, near Bruchsal. Tertiary and Mesozoic sandstones cut by faults of the Rhine Graben form the reservoir structures in this area.

In July a wildcat well drilled on the Fallstein structure, a broad Triassic anticline near Halberstadt, came in as a producer from Permian (Zechstein) dolomite. In September commercial oil was found at Gifhorn, near Braunschweig, in Wealden sandstones associated with a shallow, geophysically discovered salt plug. During the same month production was obtained at Heide, in Holstein, from the Permian Rotliegendes formation, in a structural high on which oil seepages have been known for years.

Drilling Activities

Published information indicates that during 1935 drilling totaled 574,000 ft., as compared with 436,000 ft. in 1934; 233,000 ft. in 1933 and 151,000 ft. in 1932. The German Government is subsidizing wildcat

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* Deutsche Vacuum Oel A. G., Hamburg, Germany.

TABLE 1.—*Oil Production of Germany by Fields and Oil Provinces*, 1928–1935
(Barrels of 42 Gallons)[a]

Year	Salt-dome Province								Permian Province		Rhine Valley Province	Total Production of German Reich
	Nienhagen-Hänigsen Field	Wietze-Steinförde Field	Oelheim-Eddesse Field	Oberg Field	Moelme Field	Gifhorn Field	Heide Field	Total Salt-dome Fields	Volkenroda Field	Fallstein Field	Forst Field	
1928	274,323	322,742	679	46,319				644,021				644,315
1929	310,891	337,582	10,535	67,578				719,901				720,069
1930	586,404	427,539	100,716	72,485				1,186,969	29,806			1,220,296
1931	506,548	403,634	213,549	116,088				1,242,598	360,885			1,602,517
1932	769,405	366,982	230,979	130,711				1,498,077	110,481			1,608,558
1933	1,014,853	376,628	127,211	110,131				1,628,823	40,698			1,670,109
1934	1,685,124	363,118	52,001	88,935				2,189,964	12,250			2,202,214
1935	2,318,477	351,855	53,466	195,153	47,698	4,858	10,948	2,982,455	5,229	9,156	10,871	3,007,711

[a] Official figures published in Germany are given in metric tons. For the above conversion into barrels a factor of 1 metric ton equaling 7 bbl. has been used.

drilling and of the above 1935 footage an amount of 182,000 ft. (as compared with 117,000 ft. in 1934) was drilled with subsidy money.

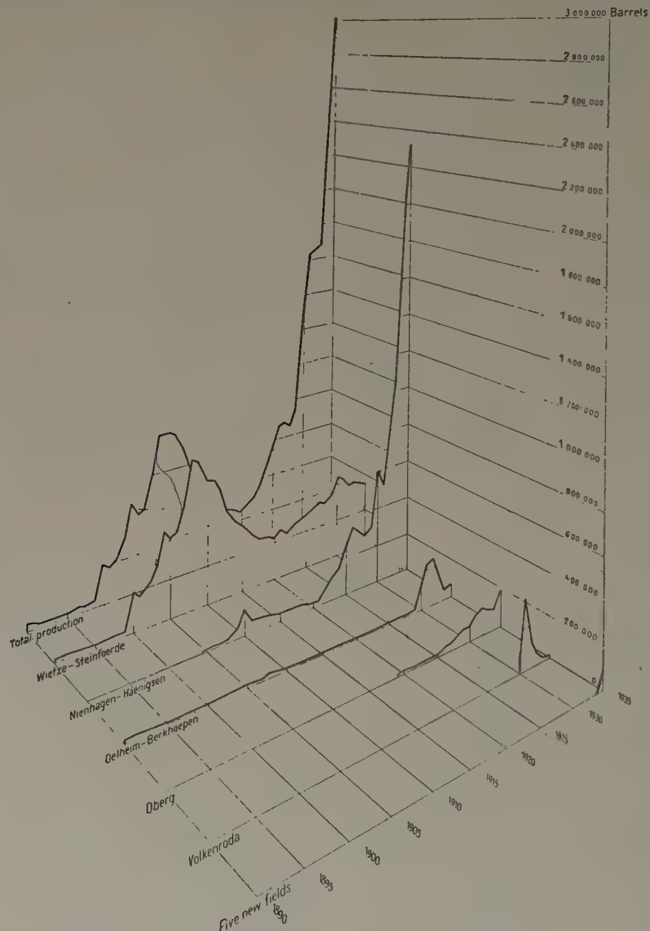

FIG. 1.—PRODUCTION OF CRUDE OIL IN GERMANY FROM 1890 TO 1935.

At the end of the year there were 43 wildcat wells drilling and about 40 wells drilling in or near producing fields.

Oil and Gas in Iran in 1935*

(New York Meeting, February, 1936)

There have been no major field developments during 1935. Operations have proceeded normally on the company's three producing fields, Masjid-i-Sulaiman, Haft Kel and Naft-i-Shah.

The refinery at Kermanshah was commissioned in September, 1935, with a rated throughput capacity of 75,000 tons a year of topped crude to meet local requirements. Crude production from the Masjid-i-Sulaiman and Haft Kel fields is tabulated below:

Year Ending Dec. 31	Masjid-i-Sulaiman[a]		Haft Kel		Total	
	Tons	Barrels, Equiv. to Nearest 10,000	Tons	Barrels, Equiv. to Nearest 10,000	Tons	Barrels, Equiv. to Nearest 10,000
1934	5,338,733	40,800,000	2,198,639	16,810,000	7,537,372	57,610,000
1935 (to Oct. 31)....	3,575,768	27,960,000	2,549,285	19,440,000	6,125,053	47,400,000
Year........					7,487,697	56,910,000

[a] Net production; i.e., excluding surplus products re-injected to the reservoir.

Masjid-i-Sulaiman Field.—The flowing lives of wells have been extended by (1) a process of acid treatment, thereby reducing the bottom-hole pressure differentials, and (2) by reducing the back-pressure.

Optimum producing conditions for individual wells have been determined as a result of an experimental study of the amount of available energy in the reservoir crude and of energy losses in flowing wells.

The return of surplus products to the reservoir has continued to be a satisfactory economic operation and the crude throughput capacity of the topping plant has been increased. The viscosity of residue returned to the reservoir is reduced before injection by regassing at 35 lb. per sq. in. absorption pressure with surplus gas.

The pressure in the gas dome is falling at the low rate of one pound per annum.

Haft Kel Field.—The delimitation of the main structure has proceeded; the oil-bearing area so far proved being about 50 square miles.

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* Received from Anglo-Iranian Oil Co., Ltd., London, England.

Possible extensions of this oilfield are being tested. Active exploitation has been continued and during the year the pipe line capacity from this field was increased.

Gasoline retention in the crude in this field is controlled by means of multistage separation and stabilization, the flowing pressures of about 500 lb. per sq. in. rendering this an economic method.

Similar methods of reservoir control as at Masjid-i-Sulaiman are in force.

Naft-i-Shah Field.—Production is drawn from this field to supply local market requirements. From the Iraq (Naft Khaneh) section of the field the production is delivered to Alwand refinery near Khanaqin. From the Iran (Naft-i-Shah) section products are piped to Kermanshah refinery, the pipe line and the topping plant having been commissioned in August, 1935.

Aerial Survey.—Aerial photography as an aid to geological studies is in progress and over 2000 square miles have been aerially surveyed to date.

Oil and Gas Production in Iraq during 1935*

By Ben B. Cox, Member A.I.M.E.†

(New York Meeting, February, 1936)

The principal events during the year consisted in the exploitation of the Kirkuk field, the regular operation of the four-million-ton pipe line to the Mediterranean, and the discovery of low-gravity oil on three other structures in the West Tigris (Shergat) area.

The Iraq Petroleum Co., Ltd. continued the systematic exploitation and exploration of its Kirkuk field, maintaining a carefully unitized operation. Bottom-hole pressure differentials and low gas-oil ratios were maintained. All crude was produced by flowing The cleaning up following the construction of the Mediterranean pipe line, which began deliveries in August, 1934, was completed during the first quarter of 1935. The line easily maintained its rated capacity for the remainder of the year.

The Mosul Oilfields, Ltd., through its operating subsidiary, the B.O.D., Ltd., expanded its exploratory organization from 9 to 16 drilling rigs and discovered 20° A.P.I. crude on the Sadid, Hibbarah and Qasab anticlines. Whether these discoveries will be commercial pools remains to be proved. The Qaiyarah-Najmah-Jawan field, which was discovered by the I.P.C. in 1928, was extended and production was found in the Eo-Cretaceous as well as the "Main Limestone" (Eocene, Oligocene and Lower Miocene). Gas caps were found under each of the crests of the West Tigris structures. Negotiations are in progress between the Mosul Oilfields, Ltd. and the Iraq Government for the extension of the Anatolian Railway from the Turkish border to Mosul, with a view to tanking the heavy West Tigris crude to the Mediterranean.

The subsidiary of the Anglo-Iranian Oil Co., Ltd.[1], the Khanaqin Oil Co., Ltd., continued to operate its Naft Khaneh field near the Iranian (Persian) border to supply the local Iraq market through the Rafidain Oil Co., Ltd.

Somewhat more than 28 million barrels of crude was produced in Iraq during 1935. Crude delivered to the pipe line for export during the years 1934 and 1935 was:

Year	Barrels[a]
1934	7,096,669
1935	27,014,904
Total as at Dec. 31, 1935	34,111,573

[a] Converted at an average of 7.6 bbl. per ton.

* Published by permission of the Near East Development Corporation. Manuscript received at the office of the Institute Feb. 10, 1936.

† Geologist, Socony-Vacuum Oil Co., Inc., New York, N. Y.

[1] Formerly called the Anglo Persian Oil Co., Ltd.

Petroleum Development in Mexico during 1935

By V. R. Garfias* and R. V. Whetsel,* Members A.I.M.E.

(New York Meeting, February, 1936)

Production of crude petroleum in Mexico during 1935 totaled approximately 40,082,000 bbl., an increase of 1,925,000 bbl. over the previous year. Successful development continued in the Poza Rica field during the year, increasing production in that area from 3,708,000 bbl. in 1934 to 9,542,000 in 1935. The output of the South fields (Golden Lane) area decreased by 3,000,000 bbl. during the year, and the heavy-oil district of the Northern fields by 1,500,000 bbl. Production in the Tehuantepec fields showed a slight gain.

Production of natural gasoline increased from 430,000 to 600,000 bbl. in 1935. Crude run to stills in local refineries is estimated at 30,000,000 bbl., some 4,000,000 bbl. more than in the previous year. Exports of crude and refined products were approximately 22,000,000 bbl., or 2,000,000 bbl. less than in 1934. Exclusive of ships bunkers, domestic consumption increased about 900,000 bbl. during the year, reaching an estimated total of 14,500,000 barrels.

Only 74 wells were completed, as compared to 148 in 1934 and 91 in 1933. In proven areas 58 completions resulted in 33 producers and 25 failures. In northeastern Mexico, near the United States border, six wildcat wells were completed, all of which gave little or no encouraging results, except Ranchería No. 3, near Camargo, which is a fair-sized gas well. Four wildcats were drilled just northeast of the Northern fields (heavy-oil district), all of which were failures. A deep test was completed a short distance southeast of the Golden Lane (South fields) in Palo Blanco, which encountered small production not sufficient to exploit. On the Isthmus of Tehuantepec a wildcat well was completed for an estimated initial production of 2000 bbl. daily, a short distance south of the old Jalapa field, which was perhaps the most important new development of the year. Four other wildcats drilled in the Isthmus district resulted in failures.

Fields

Northern Fields (*Heavy-oil District*).—In the Northern fields, 18 producing wells and 20 failures were completed, as compared to 34 producers and 71 failures in 1934. The initial production of the new

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* Foreign Oil Department, Cities Service Co., New York, N.Y.

producers was small, averaging about 40 bbl. daily per well. Production of the field totaled 10,371,000 bbl., a decrease of 12.8 per cent from the previous year. In 1934 the production dropped only 7.5 per cent. The larger decline in 1935 was due, undoubtedly, to the curtailed drilling and small initial output of the producers obtained.

South Fields (Golden Lane Area).—Only three wells, two of which were small producers, were completed on the Golden Lane structure of the south fields during the year. Production declined from 12,780,000 bbl. in 1934 to 9,731,000 bbl. in 1935, a decrease of over 23 per cent, which is the largest percentage of decline recorded in the South fields in several years. The decline was due to the closing of several wells during the month of April, to lack of new drilling and a general decline in old wells.

Poza Rica.—Six wells were completed in the new Poza Rica field during the year, four of which were producers. The two failures were important in defining the limits of the field to the north and west, while one of the producers extended the field a full kilometer to the east and another about the same distance to the south. At the close of the year two wells were drilling in the field. Production increased steadily from a daily average of 14,000 bbl. in January to 36,000 in December. Total output in 1935 exceeded that of the previous year by 5,800,000 bbl. Acid treatment was used in one of the wells at the end of the year, with considerable success.

Isthmus of Tehuantepec Fields.—Eleven wells were completed in proven areas during 1935, resulting in nine producers. The same number of wells were completed in the previous year, all of which were producers. Production increased 7 per cent over 1934, reaching a total of 10,270,000 bbl.

TABLE 1.—*Production of Oil in Mexico*
U.S. Barrels

	1934	1935	Total since Discovery to End 1935	November, 1935	Number of Producing Wells
Northern fields (11°–14° A.P.I.)	11,895,000	10,371,000	716,245,000	752,167	565
South fields, Golden Lane (20°–24° A.P.I.)	12,780,000	9,731,000	996,618,000	812,693	233
South fields, miscellaneous	194,000	167,000	4,765,000	8,526	14
Poza Rica (33°–34° A.P.I.)	3,708,000	9,542,000	14,247,000	1,013,478	12
Isthmus of Tehuantepec (32–½° A.P.I.)	9,580,000	10,271,000	69,819,000	865,910	186
	38,157,000	40,082,000	1,801,694,000		1,010

Crude Oil Prices and Taxes

The price of heavy crude spot cargoes f.o.b. Tampico, excluding export and production tax, held firmly at $1 per barrel during the first half of

1935. By September the price dropped to 85¢, which held until the close of the year. In 1934 the price increased from 74¢ in January to $1 in September. The average price was 60¢ in 1933, 44¢ in 1932, 55¢ in 1931, 60¢ in 1930, 65¢ in 1929 and $1.05 in 1928.

The price of southern crude not controlled by local refineries increased from 35¢ a barrel at the well to 40¢ during 1930. Poza Rica crude, being controlled entirely by local refineries, recorded no sales either in the field or f.o.b. ship.

TABLE 2.—*Mexican Oil Taxes*
Per U.S. Barrel

	December, 1934	December, 1935
Heavy crude	$0.11654	$0.097456
Light crude	0.18783	0.157648
Fuel oil	0.16765	0.138174
Refined gasoline	0.12344	0.121931
Crude gasoline	0.26411	0.261566
Refined kerosene	0.08419	0.081833
Crude kerosene	0.17236	0.168137
Lubricants (per ton)	0.14850	0.148265

OUTLOOK FOR 1936

Drilling activity and production in the Northern fields and the South fields (Golden Lane area) is expected to further decline in 1936. Further drilling will decidedly increase output in Poza Rica, and further development stimulated by the new discovery well on the Isthmus of Tehuantepec may also increase production in that district. It is reasonable to expect that despite declining production in the old North and South fields, increasing output of Poza Rica and Tehuantepec may bring Mexican production to a total of 44,000,000 bbl. in 1936.

Oil and Gas Production in the Netherlands East Indies and Sarawak*

(New York Meeting, February, 1935)

Line Number	Administration	Age, Years to End of 1935	Total Oil Production, Bbl. To End of 1935	Total Oil Production, Bbl. During 1934	Total Oil Production, Bbl. During 1935	Total Oil Production, Bbl. Daily Average during Nov., 1935	Average Oil Production, Bbl. per Well Daily during Nov., 1935	Total Gas Production, Millions Cu. Ft. During 1934	Total Gas Production, Millions Cu. Ft. During 1935
1	North Borneo	26	67,948,825	4,682,000	5,052,000	12,789	30	4,152	3,558
2	East Borneo	40	318,731,660	13,562,000	12,876,000	31,855	46	8,350	8,679
3	Ceram	39	4,682,705	253,000	288,000	821	21	40	38
4	Java	48	73,864,633	3,693,000	3,404,000	10,125	24	2,474	2,575
5	South Sumatra	39	124,001,358	8,305,000	8,451,000	27,080	78	11,299	11,618
6	North Sumatra	50	107,076,895	8,342,000	7,280,000	15,533	181	6,471	7,019
7	Total		696,306,076	38,837,000	37,342,000	98,203	49	32,786	33,487
				+10,623,938† of which 94,962 was in Java, remainder in S. Sumatra	+13,560,000† of which approximately 100,000 was produced in Java, remainder in S. Sumatra				

† Recent figures from another source.—Ed.

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1935	During 1935: Completed	During 1935: Abandoned	At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Producing Gas Only	At End of 1935: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Flowing	Pumping	Gas-air Lift
1	520	15		17	441	1	459	340–5,280	130–5,242	15	394	32
2	1,279y	35	8		688	1	689	230–2,620	210–2,600	18	655	15
3	75				39		39	260–1,020	240–1,000		39	
4	1,350y	2		40	416		456	160–2,950	130–2,880	7	407	2
5	1,607y	28	11	21	346	2	369	290–5,400	160–5,200	75	90	181
6	713	1		20	85	1	106	300–4,140	260–4,100	25	30	30
7	5,544y	81	19	98	2,015	5	2,118			140	1,615	260

* Received through the courtesy of N.V. de Bataafsche Petroleum Maatschappij, The Hague, The Netherlands.

Line Number	Producing Rock					Number of Dry and/or Near dry Holes to End of 1935	Deepest Zone Tested to End of 1935	
	Name	Age[g]	Character[h]	Porosity[i]	Structure[j]		Name	Depth of Hole, Ft.
1	Seria- and Miri formations	Mio	SsH	18	AF	80	Miri deep shale	6,180
2	Balik Papan-Poeloe Balang and Tarakan formation	Pli + Mio	SsH, S	10–30	Af	199y	Poeloe Balang	5,250
3	Boela formation + Triassic	Pli + Tri	SsH	y	Af	40	Triassic	2,400
4	Mergelklei—Globigerinae—Orbitoid zones	Pli + Mio	S, SH, LS	15–35	Af	308y	Basis mergelzone	5,900
5	Palembang- and Telissa zones	Pli + Mio + Paleogene	S, SH, SS	13–28	Af	344y	Under Telissa	7,550
6	Seuroela-Keutapang-Grensklei zones	Pli + Mio	S, SH, SS	y	Af	242y	Grensklei	6,680

[g] Footnotes to column heads and explanation of symbols are given on page 215.

Petroleum Development in Peru during 1935

By Oliver B. Hopkins,* Member A.I.M.E.

(New York Meeting, February, 1936)

Peruvian production for the year 1935 amounted to 17,064,879 bbl., a record amount for any year, bringing the cumulative production of the country up to 188 million barrels. The 1935 figure is an increase of 785,769 bbl. over the 1934 total. The property of the International Petroleum Co. contributed 636,812 bbl. of this increase, and the Lobitos property 158,625 barrels.

Exploration work in the country was again active, with attention focused on three areas, the Huallaga River, Lake Titicaca and the Coastal Zone of the Province of Tumbes. It is reported that in the Huallaga River area the Selden Breck Construction Co. has completed geological and engineering studies on its Pachitea River concessions and has ordered a drilling rig. In the Lake Titicaca region further studies in the vicinity of Pusi were made by Government geologists. During the period from 1906 to 1915, the Pirin anticline in this area produced 285,936 bbl. of low-grade crude. The Government holds 120,000 hectares of reserved lands in this area. In the Coastal Zone of the Province of Tumbes explorations by the Government were continued on the National Reserve, and a test location has been selected in the Quebrada Zapotal about 10 miles from the Port of Zorritos. An order has been placed in the United States for drilling equipment.

LaBrea-Parinas Estate.—Production on the LeBrea-Parinas Estate reached an all-time high in 1935 of 14,756,914 bbl., an increase of 636,812 bbl. over the 1934 record. The total production from 1890 to 1935 was 148,541,523 bbl. During 1935 a total of 63,021 ft. was drilled in new wells and 5449 ft. in deepening existing wells; 23 wells were deepened and 29 new wells were completed, of which 27 were producers and 2 were dry holes. At the end of the year 2873 wells had been drilled on the Estate, of which 1838 were still productive. The remaining 1035 wells represent abandoned producers or dry holes.

Practically all the drilling on the property has been done with cable tools, but during 1934 three strings of rotary tools were introduced. Experience with these outfits has shown that rotary equipment can

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* Chief Geologist, Imperial Oil, Limited, Toronto, Ontario.

satisfactorily and economically drill the various formations encountered, and is necessary to handle the high pressures in the newer areas. The wells are produced by flowing, gas-lift and pumping methods. In recent years careful attention has been given to the older wells, cleaning them out and deepening when required. The result has been very beneficial, as is indicated by the fact that wells completed prior to 1921 produced substantially the same amount of oil in 1934 as in the year 1922.

Since 1927 large quantities of gas, generally amounting to 50 to 60 per cent of that produced, have been returned to the producing sands in selected areas in the field and thus, by partly or completely maintaining reservoir pressures in these areas, it is expected that the ultimate yield may be greatly increased.

During the year experiments in water-flooding and acidation were commenced, but neither of these operations has reached the point where the results may be judged.

TABLE 1.—*Oil and Gas Production in Peru in* 1935

Line Number	Field, *Department*	Age, Years to End of 1935	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1935	During 1934	During 1935	Daily Average during Nov., 1935
1	LaBrea-Parinas, *Piura*	46	*y*	*y*	*y*	*y*	148,541,523	14,130,102	14,756,914	39,071
2	Lobitos and Restin, *Piura*	31	*y*	*y*	*y*	*y*	36,204,178	2,101,340	2,259,965	6,230
3	Zorritos, *Tumbes*	52	*y*	*y*	*y*	*y*	3,041,689	47,668	48,000	*y*
4	Pirin (Huacane), *Puno*		*y*	*y*	*y*	*y*	285,936	0	0	0
5	Total		*y*	*y*	*y*	*y*	188,073,326	16,279,110	17,064,879	*y*

Line Number	Average Oil Production, Bbl.			Total Gas Production in Millions of Cubic Feet				Number of Oil and/or Gas Wells							
									During 1935		At End of 1935				
	Per Acre to End of 1935[b]	Per Acre-foot to End of 1935	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[a]	Producing Gas Only	Total Producing
1	*y*	*y*	23.5	*x*	*x*	*x*	*x*	2,317	27	2	131	*y*	1,698	9	1,838
2	*y*	*y*	*y*	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
3	*y*	*y*	*y*	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
4	*y*	*y*	0	*x*	0	0	0	*y*	0	0	0	0	0	0	0
5	*y*	*y*	*y*	*x*	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*

[a] Footnotes to column heads and explanation of symbols are given on page 215.

Lobitos Property.—This property, which is north of the LaBrea-Parinas Estate, produced during 1935 a total of 2,259,965 bbl., bringing the cumulative production to the end of 1935 to 36,204,178 bbl. To the end of 1934, there had been drilled 859 wells, of which 612 were producers at that time. There are two producing fields on this property, one at Lobitos and the other about 15 miles farther north, at Cabo Blanco and Restin. Production comes from the Eocene and Oligocene, or, generally speaking, from beds of the same age as are productive on the LaBrea-Parinas Estate. To the end of 1934 total footage of all wells drilled amounted to 1,981,923 ft. The company has recently completed a refinery at Ellesmere Port, England.

Zorritos Property.—On this property, operated by Piaggio & Co., 383 wells have been drilled to Dec. 31, 1934, of which 40 are still productive. It is estimated that the 1935 production amounted to 48,000 bbl., bringing the total to date up to just over 3 million barrels. The production here comes from beds considered to be of Miocene age. The total footage drilled to the end of 1934 amounted to 416,298 feet.

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1935						Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1935				
			Number of Wells							Average at End of		Gravity A.P.I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Misc.	Injection into Reservoir[d]	Initial	1934	1935	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	y	y	32	1,616	13		11	35	x	x	x	HCT 39.6 LCT35.2	HCT39.0 LCT34.5	HCT39.3 LCT 34.7	y	M
2	y	y	y	y	y	y	y	y	x	x	x	y	y	y	y	y
3	y	y	y	y	y	y	y	y	x	x	x	y	y	y	y	y
4	y	y	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	y	y	y	y	y	y	y	y	x	x	x	y	y	y	y	y

Line Number	Character of Gas Approx. Average during 1935		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1935 (Exclusive of Drilling Difficulties)	Deepest Zone Tested to End of 1935	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average, Ft.	Structure[j]		Name	Depth of Hole, Ft.
1	y	y	Verdun, Lomitos, Parinas, Negritos, Salina	Eocene and Oligocene	S	y	x	AF	425	?	6,266
2	y	y	Terebratula, Lower Cáverno	Eocene and Oligocene	S	y	x	AF	y	Probably Cretaceous	?
3	y	y	Zorritos	Miocene	S	y	x	MF?	y	?	2,900?
4	0	0	y	y	y	y	x	y	y	?	?
5	y	y									

Oil and Gas Production in Poland*

(New York Meeting, February, 1935)

The attached tables show that in 1935 production of crude oil in Poland slightly decreased (minus 14,450 tons) and that gas production

Table 1.—*Oil and Gas Production in Poland*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres			
			Oil	Oil and Gas	Gas	Total
	Jaslo District					
1	Lipinki, Libusza, Kryg, Kobylanka, Dominikowice, Wojtowa, *Gorlice*	70	1,778[1]			1,778
2	Korczyna-Biecz, *Gorlice*	38	55			55
3	Sękowa-Ropica Ruska, *Gorlice*	63	100			100
4	Harklowa, *Jaslo*	65	370			370
5	Roztoki-Sadkowa, Dobruc, Bialk. Brzez, *Jaslo*	26			148	148
6	Męcinka, Jaszczew, *Jaslo-Krosno*		889	445		1,334
7	Potok-Toroszówka, *Krosno*	44				
8	Krosno-Krościenko, *Krosno*	47				
9	Bóbrka-Rowne-Rogi-Wietrzno, *Krosno*	77	692			692
10	Iwonicz-Klimkówka, *Krosno*	45	494			494
11	Ropianka, *Krosno*	67	30			30
12	Strachocina-Gorki, *Brzozow-Sanok*	7			494	494
13	Ziennica-Turzepole, *Brzozow*	39	49			49
14	Starawieś-Brzozow-Humniska-Grabownica, *Brzozow-Sanok*	39		321		321
15	Węglowka, *Sanok*	48	148			148
16	Lubatówka-Wulka, *Sanok*	47	185			185
17	Mokre, *Sanok*	23	25			25
	Total Jaslo		4,815	766	642	6,223
	Drohobycz District					
18	Wankowa-Ropienka-Paszowa-Stankowa, *Lesko*	49	519			519
19	Rajskie, *Lesko*	49	37			37
20	Lodyna, *Lesko*	49	49			49
21	Strzelbice, *Sambor*	54	62			62
22	Opaka, *Drohobycz*	39	25			25
23	Boryslaw (deep "skiba"), *Drohobycz*	41		3,700		3,700
24	Rypne-Duba-Perehinsko, *Dolina*	48	1,480			1,480
25	Daszawa, *Stryj*	14			1,250	1,250
26	Schodnica-Urycz, *Drohobycz-Stryj*	63	1,110			1,110
	Total Drohobycz		3,282	3,700	1,250	8,232
	Stanislawow District					
27	Bitkow, *Nadworna*	36		1,480	247	1,727
28	Pasieczna, *Nadworna*	55				
29	Majdan-Rosulna, *Stanislawow*	46	222			222
30	Sloboda Rungurska, *Peczenizyn*	60	119			119
	Total Stanislawow		341	1,480	247	2,068
31	Other fields		1,267			1,267
32	Total		9,705	5,946	2,139	17,790

[1] The figures for acres proved have been changed in several instances by Dr. Tolwinski from those given by Professor Bohdanowicz last year, therefore the figures for barrels per acre are changed and comparisons with previous reports is difficult.

* This information was received through the courtesy of Professor Charles Bohdanowicz, of Warsaw. The tables were prepared by Dr. K. Tolwinski, of the Boryslaw Geological Station. Manuscript received at the office of the Institute March 26, 1936.

increased (plus 16,455,000 cu. m.). The decrease in production of crude oil was due mainly to the continuous exhaustion of the Boryslaw fields and the fact that only a small number of wells were drilled, whereas the increase in gas production was due not only to the exploitation of new wells but also to a general improvement in the methods used.

As in preceding years, drilling was almost exclusively devoted to the exploration of extensions of oil fields in the Jaszlo and Stanislawow districts. Favorable results were obtained in the Jaszlo district on the extension of the Roztoki gas field (well No. 7, depth 1300 m.) and in one of the old fields oil was obtained from Cretaceous deposits (well Maxymiljana, depth 1150 m.). In the Stanislawow district well No. 11, on the extension of the Chrobry field in Pasieczna, had a daily initial yield

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
	To End of 1935[2]	During 1934	During 1935	Daily Average during Nov., 1935	Per Acre to End of 1935[b]	Per Well Daily during Nov., 1935	To End of 1935	During 1934	During 1935	Maximum Daily during 1935	Completed to End of 1935	During 1935: Completed	During 1935: Abandoned
1	2,498,530	141,690	183,960	610	1,405[1]	0.2		35	45	0.134	780	30	3
2	318,735	31,410	30,465	73	5,795	2.8		35	56	0.166	46	3	
3	710,650	4,660	3,860	10	7,106	0.2					160		
4	1,579,940	61,450	59,860	161	4,270	1.2		41	54	0.116	269	7	2
5	278,900	3,700	7,690	18	209	5.3	39,441	1,310	2,028	9.012	14	2	1
6		39,190	45,630	204				1,764	1,486	6.234	35		
7	5,214,516	91,203	93,940	247	5,825	3.3		231	179	6.014	243	10	2
8	1,885,920	37,840	33,550	89		2.0		11	6	0.018	107		
9	5,375,315	76,245	69,920	182	7,767	2.2		180	164	0.530	244	1	
10	923,370	11,800	15,725	386	1,869	0.7		18	29	0.088	50	4	1
11	201,390	1,641	1,830	81	6,713	0.5		4	23	0.102	35	3	
12							669	45	155	0.519	13		
13	646,480	19,810	17,375	45	13,193	1.3		42	37	0.120	60		
14	1,752,590	115,645	97,450	237	5,460	4.2		495	385	1.112	102	2	1
15	1,947,105	26,040	30,380	76	13,156	1.0		26	22	0.070	222	2	
16		20,625	16,230	45		2.7		21	21	0.064	75		
17	49,185	3,415	3,960	16	1,967	1.6					17		1
	23,382,626	686,364	711,825	2,480	74,735		40,110	4,258	4,690	24.299	2,472	64	11
18	5,698,215	170,510	178,140	492	10,980	1.6	816	40	55	0.166	381	13	1
19	66,360	3,560	5,085	12	1,793	1.1		1	4	0.014	26	2	
20	130,610	2,035	2,035	4	2,665	0.2					42		
21	564,370	20,590	19,110	55	9,100	1.4	73	11	12	0.034	73	2	
22	130,130	3,900	3,360	8	5,205	1.7					15		
23	176,305,260	2,204,700	2,098,760	5,740	47,650	8.9	175,418	5,454	4,865	13.862	1,282	9	5
24	2,042,470	167,435	149,030	378	1,380	3.3	4,333	474	432	1.295	216	7	4
25							36,923	4,520	5,050	19.062	19		
26	19,192,610	337,675	330,995	928	17,290	1.8	1,312	186	192	0.554	756	17	2
	204,130,025	2,910,405	2,786,515	7,617	96,063		218,875	10,686	10,610	34.987	2,810	50	12
27	5,899,218	195,335	206,250	577	3,873	5.4	25,065	1,414	1,376	3.879	168	8	4
28	790,865	30,910	25,000	66		2.1		121	132	0.420	191		
29	350,690	23,555	21,360	59	1,580	1.0					100	6	1
30	2,605,320	14,090	13,120	34	21,893	0.6					300		
	9,646,093	263,890	265,730	736	27,346		25,065	1,535	1,508	4.299	759	14	5
31		48,400	48,900	132		0.6		75	23			17	
32	237,158,744	3,909,059	3,812,970	10,965	198,144		284,050	16,554	16,831	63.619	6,041	145	28

[2] Data for December and partly for November estimated.
[b] Footnotes for table headings and explanation of symbols are given on page 215.

of 25 tons from a depth of 1113 m. The settled production was maintained at 10 tons per day during several months.

A considerably increase in leasing activity led to the discovery of oil in a test well near Lipie (outside Boryslaw district) at a depth of only 95 m., from Krosno beds (Oligocene). The initial yield was 20 tons of oil per day with a considerable quantity of water. However, within a week's time the oil yield dropped to 2 tons per day. In former years wells had been drilled in this general region (in the Polana and Rajskie fields) which sometimes even gave flowing production, but this large initial production always dropped rapidly, especially when the wells were deepened, down to the economic limit usual for this region, which is 5 to 10 tons per month. On the other hand, wells in the vicinity of these producers frequently gave only water.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells, At End of 1935: Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Oil Production Methods at End of 1935, Number of Wells: Pumping	Air-lift	Misc.	Injection into Reservoir[d]	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1934	1935	Character of Oil, Approx. Average during 1935, Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Base, Asphalt, or Paraffine, Per Cent
1	14	435		1	436	1,310	416		25					33	38	34	5.9–8.4 P
2	1	26			26	1,150	25		1					39	42	40	0.3–1.1 A
3	6	45			45	820	42		3					35	49	43	
4	2	130		1	131	1,280	128		3					21	27	26	0.8 A
5	2			8	8	3,280			8		1,647	1,420	1,420				
6		4	10	16	30	3,120			30		1,562	923	852	41	43	42	4.0–6.8 P
7	8		73	1	74	2,300	72		2					39	46	41	0.4 A
8	4	45			45	1,800	45							29	33	31	0.7–8.0 M
9	2	79	2		81	2,130	50		31					33	38	35	0.5–6.2 M
10	7	55			55	1,640	50		5					21	45	29	
11	3	15		2	17	1,640	12		5					31	38	34	0.4 A
12	1			2	2	2,590 to 3,840			2		1,350	710	710				
13	1	34			34	1,480	29		5					33	34	34	6.7 P
14	7		55	2	57	2,300	28		29					39		43	0.3–4.0 M
15	3	81			81	1,050	79		2					27	31	29	0.4 A
16	2	17			17	1,480	16		1							36	0.3 A
17		10			10	1,800	9		1					43	44	43	0.3 A
	63	976	140	33	1,149		1,001		153		4,559						
18	20	309		1	310	1,310	307		3					31	37	36	0.5–5.9 P
19	6	10			10	1,310	10							41	44	42	0.7–5.1 PA
20	3	20			20	985	19		1					36	38	37	5.2–5.8 P
21	9	38			38	660	38			1				31	33	32	6.2–6.6 P
22	1	5			5	1,970	5							42	44	43	5.4–6.1 P
23	235		529	121	650	4,270	35		615					31	37	33	9.6–8.1 P
24	3	116			116	2,625	105		11					33	39	36	4.6–8.0 P
25	2			16	16	2,300			16		852	639	639				
26	146	510			510	1,480	506		4	11				28	40	35	0.3–5.9 AP
	425	1,008	529	138	1,675		1,025		650		852						
27	12		96	11	107	3,610	3	7	97					35	62	44	0.2–8.4 P
28	12	31			31	660 to 4,760	10		21		2,272	1,420	1,420	41	53	49	0.5–3.8 P
29	3	62			62	1,150	46		16					30	36	33	0.8–1.1 A
30	3	53			53	985	51		2					37	39	38	5.2–5.9 P
	30	146	96	11	253		110		136		2,272						
31	189	199		4	203		92		103								
32	707	2,329	765	186	3,280		2,228		1,042		7,683						

Intensive geological and geophysical (reflection method) research work carried out by the Pionier Company in the sub-Carpathian zone, especially in the part that surrounds the Daszawa gas fields, will probably facilitate the commencement in the near future of the drilling of prospecting wells, which will have to clear up not only the question regarding the extension of the gas fields but also the problem of the presence of oil-bearing horizons in the Miocene beds of this large zone.

Government measures relating to forced exports of petroleum products during the last three years, and the permission granted to small refineries to abstain from unprofitable exports, have permitted the collection of an amount of over Zl 3,000,000,* which will be used for the creation of a fund to be devoted to exploration drilling to discover new oil fields. The plan for such exploration drilling for the year 1936–37 will be elaborated by representatives of the existing petroleum organizations with the participation of representatives of the State Mining Department.

TABLE 2.—*Feet Drilled and Wells Completed in Poland*

District	Total Feet Drilled		Number Wells Completed	
	1935	1934	1935	1934
Jasło	124,350	123,704	90	100
Drohobycz: Borysław	35,107	26,314	9	9
Drohobycz: Outside	76,447	70,767	42	47
Stanisławów	41,340	34,913	15	9
Total	277,245	255,698	156	165

TABLE 3.—*Production of Some Recently Completed or Deepened Wells*

	Average Daily Production per Well, Initial Rather than Settled, Bbl. per Day	Average Daily Settled Production, Bbl. per Day
Jasło district, average of 19 wells	10.8	4.3
Borysław: well Stateland 27	73.1	50.2
well Stateland 28	58.5	21.9
well Łukasiewicz	36.5	32.9
Rypne, average of four wells	8.9	3.6
Wańkowa, average of eight wells	13.7	5.9
Bitków, average of six wells	45.3	23.4

* At exchange of 5 Zloty = $1, this is $600,000.

Petroleum Development in Rumania in 1935

(New York Meeting, February, 1936)

Both drilling and production of oil decreased in Rumania during 1935. The drilling totaled 1,042,041 ft. and production 61,973,938 bbl., being a decrease of 8.5 and 1.6 per cent, respectively. Wells completed during the year totaled 198, of which 168 were oil wells, compared with 238 and 215, respectively, of 1934.

Table 1.—*Summary of Petroleum Production in Important Fields of Rumania during* 1935

	Production, Bbl.		Drilling, Ft.[1]		Wells Completed		Average Initial Production
	Total in 1935	Increase or Decrease	Total Depths Completed Wells	Increase or Decrease	Total	Oil Wells	
Moreni, Gura-Ocniţei, Ochiuri, etc.	37,166,718	−4,562,165	539,405	−238,124	111	99	530
Boldeşti	11,528,945	+ 756,712	213,591	+ 25,480	27	26	1,250
Bucşani	4,999,700	+4,947,706	172,953	+167,185	30	24	2,185
Baicoi-Tinea	600,284	− 151,213	12,799	+ 8,836	3	1	300
Ceptura	2,599,451	− 514,229	0	− 4,167	0	0	0
Ariceşti	1,731,186	−1,059,933	36,045	− 47,868	6	4	730
Bustenari-Runcu	2,226,489	− 310,871	21,448	− 22,372	9	8	285
Others	1,121,165	− 135,174	45,800	+ 15,451	12	6	170
Total	61,973,938	−1,029,167	1,042,041	− 95,579	198	168	860

[1] Footage drilled is given for total depths of completed wells inasmuch as regular footage statistics are not accurate. Drilling in gas fields of Transylvania not included.

No important discovery was made during the year. The only new field found was Valea Calugareasca, where the Credit Minier completed a small well on the westward plunge of the anticline. Drilling higher on the structure will probably prove the field to be of greater importance than the results of the discovery well indicate. The only other developments of importance were the extension of the Bucșani field, the opening up of a new area on the northeast of the salt at Moreni by Credit Minier and a minor extension of the West Gura Ocniței field. At Calinești, on the east extension of the Moreni field, exploration work continued and a gas well was completed, but oil in commercial quantities is yet to be found.

An important test was started south of Ploeşti, the first to be drilled in this portion of the Rumanian plain.

Several wildcat wells are drilling on the Margineni anticline, an untested prospect between Aricești and Bucşani. Another wildcat is being drilled at Podeni Vechi, to the northeast of Boldesti.

During 1936, Concordia plans to drill one or two wildcats along the south of the salt between Baicoi and Tintea.

Exploration work is hampered by the present regulations governing the granting of land. The maximum area granted is 2500 acres and the explorer receives a concession on only a small part of the total area proved

TABLE 2.—*Summary of Development in Principal Rumanian Fields to Date*

No.	Field, District	Area Proved, Acres	Total Oil Production, Bbl.		Daily Average during Dec. 1935, Bbl.	Number Wells Completed to End of 1935	Producing Formation
			During 1935	To End of 1935			
1	Câmpina	800	266,560	32,374,575	700	277	Meotic-Pliocene
2	Buştenari, Runcu, etc.	4,200	2,226,489	96,889,536	5,600	1,639	Meotic-Pliocene
3	Ochiuri, Razvad, Gura—Ocniţei, Moreni, Piscuri, Diteşti	13,500	37,166,718	393,412,163	93,100	2,320	Dacic and Meotic Pliocene
4	Băicoi, Tintea	800	600,284	31,676,394	1,600	574	Dacic and Meotic Pliocene
5	Bucşani	2,500	4,999,700	5,051,694	33,500	31	Meotic-Pliocene
6	Aricesti	900	1,731,186	5,546,236	4,200	49	Meotic-Pliocene
7	Boldeşti	4,100	11,528,945	44,002,223	30,300	107	Meotic-Pliocene
8	Ceptura	1,700	2,599,451	25,372,155	7,100	179	Meotic-Pliocene
9	Arbănaşi	400	330,400	14,814,870	900	110	Meotic-Pliocene
10	Moldova	700	372,390	12,134,493	1,000	225 ±	Miocene, Oligocene, Eocene
11	Others (producing 1935)	1,000	151,815	5,208,819	200	15 ±	
12	Others	1,300 +		6,318,140		100 ±	
	Total	31,900	61,973,938	672,801,298	178,200	5,626	

on the basis of his work. If the whole of the 2500 acres should be proven up, a concession is given on only 800 acres. In addition to this unfavorable feature, the concession carries royalty obligations on a sliding scale of from 15 to 53 per cent, depending on the total production of individual wells. Under such conditions, exploration work can hardly be expected to progress fast enough to furnish new areas containing reserves equal to oil produced. It can therefore be predicted with reasonable certainty that Rumania will soon begin to show declining production, and that the decline will continue until more favorable laws are enacted. In this connection, it is interesting to note that only two fields of major importance have been discovered since the war, Boldeşti and Bucşani, and

most of the increase in production has been permitted by extensions to deeper drilling in the old Moreni and Gura Ocniţei field.

The importance of gas conservation, bottom-hole pressure measurements, and in general modern production practice, is gaining increased recognition, but again because of laws being unfavorable, little progress can be made. Practically all fields are highly competitive and the small concessions, only 100 acres, sold by the Government in newly proved areas on the basis of the existing laws, result in the new field being even more competitive than some of the older, where from private landholders it has been possible to block in fairly large areas.

Russian Oil Industry in 1935

By Basil B. Zavoico*

(New York Meeting, February, 1936)

The developments in the Russian oil industry during 1935 marked a very definite turning point from the time when the industry was being educated to the modern methods of oil-field finding and development, refining, transportation and marketing, to the time when the industry has thoroughly assimilated the modern technique and is now firmly standing on its own feet, as is shown by the remarkable qualitative, if not quantitative, progress in 1935. The oil industry promises that 1936 will be a record year in every respect with both quantity and quality approaching the desired high levels and standards. More particularly the Soviet Government is beginning to be successful in the development of new fields and such new production in geographically strategical points of the country will be in the coming years a factor of great importance in the industrial life of the country. The most notable achievements of the last year have been: the very successful development of the Ishimbaevo oil field in the Lower Oural-Permian Basin; the discovery and development of several promising oil fields in the Puta district of Azerbaijan, while large flush production of Baku area was extended 50 miles due southwest into the Saliani-Aliat district, where a 3000-bbl. well was completed early in 1936 at Pirsagat. Also, an apparently important discovery was made at Zikh, on the Apsheron Peninsula proper. These discoveries, as well as several important strikes in the deeper producing sands in the older fields of the Apsheron Peninsula, have greatly augmented the proven reserves of Russia and made them available either at the points where transportation facilities were already present or at points not too far distant from major industrial centers of the country. Of course, not all objectives were achieved during the past year, and several major difficulties remain to be solved in the coming years, the more important of which are: (1) supply of equipment and of parts; (2) the unavailability of competent technical men in sufficient numbers, which more particularly affects the distant fields; and (3) the problem of distribution of oil products throughout the country, especially the question of handling the needs of small consuming areas, which, while individually unimportant, in the aggregate require huge distribution.

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The exports from U.S.S.R. continued their decline in 1935. The decline in foreign shipments has been due to the increase in domestic consumption without corresponding increase in production of exportable products. The total shipments for the first nine months of 1935 dropped 21.4 per cent below the exports for the corresponding period of 1934, while the value of exports declined 32.0 per cent, owing principally to the decline of 44.5 per cent in the exports of the most valuable product, gasoline. It must be indicated, however, that the Soviet Government is not anxious to increase or even maintain its exports of petroleum products in order to secure foreign currencies for purchases abroad, because the Soviet Union is becoming more and more self-sufficient industrially as each year goes by and, also, the gold production is more than sufficient for such immediate requirements.

Production

In 1935 the total production of crude oil, 176,680,000 bbl., or 484,000 bbl. per day, exceeded the production of the preceding year, 1934, by 4.42 per cent, when 169,200,000 bbl., or 464,000 bbl. per day, was produced. Production in 1935 amounted to 79.90 per cent of the proposed plan, which anticipated production of 220,800,000 bbl. during the year.

Azerbaijan (*Southeast Caucasus*).—The oil fields of Azerbaijan continue to be the most important single source of crude oil, accounting in 1935 for 79.90 per cent of the total production of crude oil in the Soviet Union, producing in that year 136,430,000 bbl., or 373,000 bbl. per day. Thus the fields of the Apsheron Peninsula not only sustained the increased production of 1933 and 1934 but even further advanced their output to the highest level in the history of the development of the area. The increase of production in Baku and its maintenance, as well as the probability of its future increase in the coming years, has been due entirely to the discovery and development of new fields on the Peninsula, and to the discovery of deeper prolific horizons in the older fields. Lok-Batan, Kala and Kara-Chukhur have been the most important recent discoveries, while deeper production and extensions of major importance were uncovered in all the older large fields in Baku, more particularly in Balakhani-Ramani-Sabunchi, in Bibi-Eibat and on Artem Island. Deeper production in the XVII horizon of the old Bibi-Eibat has in fact rejuvenated that field. More recent discoveries, which have possibilities of developing into large fields, are: the Puta district southwest of Bibi-Eibat where, during the last year large gushers were completed in Kizil-Tepe and in Koushkhan, in addition to the Lok-Batan, which already is a fully developed major field. In Kizil-Tepe a large well was completed on Jan. 2, 1936, which produced 3500 bbl. per day initially of 36° gravity crude oil from a total depth of 2200 ft., while in Koushkhan on Feb. 10,

TABLE 1.—*Production of Crude Oil in U.S.S.R.*
MILLIONS OF BARRELS

Year	Total Production			Production by Major Districts											
				Azerbaijan (Azneft)		N.E. Caucasus (Grozneft)		N.W. Caucasus (Maineft)		Oural-Permian Basin (Bashneft)		Emba (Embaneft)		Far East (Sakhalinneft)	
	Actual	Plan	Percentage of Fulfillment	Production	Percentage of Total	Production	Percentage of Total	Production	Percentage of Total	Production	Percentage of Total	Production	Percentage of Total	Production	Percentage of Total
1916	72.80			55.81	76.55	12.73	17.48	0.40	0.55			1.82	2.50		
1920–1921	26.60														
1921–1922	32.90														
1922–1923	37.17			25.30	68.05	10.90	29.32					0.97	2.61		
1923–1924	44.40			31.30	70.45	11.80	26.55	0.25	0.56			0.90	2.03		
1924–1925	51.12			33.90	66.15	15.14	29.55	0.40	0.78			1.43	2.79		
1925–1926	59.89			39.98	66.70	18.00	30.00	0.34	0.57			1.57	2.62		
1926–1927	73.98			49.00	66.20	22.79	30.80	0.36	0.49			1.83	2.47		
1927–1928	82.60			54.15	65.50	25.90	31.30	0.41	0.50			1.82	2.20		
1928–1929	96.80			62.10	64.20	30.60	31.60	1.80	1.86			1.86	1.93		
1929–1930	124.00			73.60	59.40	44.11	35.60	3.00	2.42			2.46	1.98		
1931	156.10			92.80	59.45	56.50	36.20	3.30	2.11			2.00	1.28		
1932	149.72			88.37	59.00	53.90	35.95	3.55	2.37			1.70	1.14		
1933	149.90	170 80	87.60	107.30	71.51	34.10	22.75	4.14	2.76			1.38	0.92		
Daily prod.	0.410	0.467		0.294		0.093		0.014				0.0038			
1934	169.20	214.90	78.65	133.00	78.50	23.60	13.96	6.57	3.88			1.68	0.99		
Daily prod.	0.464	0.588		0.364		0.065		0.018				0.0046			
1935	176.68	220.80	79.90	136.430	77.21	23.31	13.20	8.34	4.72	2.84	1.61	1.70	0.97	1.65	0.93
Daily prod.	0.484	0.605		0.373		0.064		0.023		0.0078		0.0047		0.0045	
1936		200.00		154.000	77.00	23.30	11.73								
Daily prod.		0.548		0.422		0.064									

1936, well No. 202 was completed for 2200 bbl. initially from a total depth of 5000 ft. In old Balakhani field the deeper exploration in pre-Kirmaku section resulted in well No. 975 with an initial production of 5600 bbl. per day from a total depth of 5900 ft. Important extensions of the producing territory in Azerbaijan during the past year included: (1) the discovery of the Zikh field on the southernmost extension of the main structural axis of the Apsheron Peninsula, which includes the Binagadi, Balakhani-Ramani-Sabunchi, Surakhani and Kara-Chukhur fields, where, in July of 1935, after extensive and protracted exploration, well No. 12 was completed for 7000 bbl. per day initially from a total depth of 5700 ft.; (2) the discovery of major production in Pirsagat in Saliani steppes, where on Feb. 9, 1936, well No. 27 was completed for 3000 bbl. per day initially of 34° gravity crude oil from a total depth of 4120 ft., thus extending the probable producing area of Apsheron Peninsula some 50 miles southwest from Baku, and, therefore, vastly increasing the crude-oil reserves of Azerbaijan.

The recompletion of many of the old producers played an important part during the past year, with the management of the fields finally paying as much attention to a large number of small wells as formerly they did to a few large gushers, which naturally could not be relied upon for sustained production. This particular development was probably one of the healthiest in U.S.S.R. during the past year and was noted not only in the old fields where small pumping wells were being very carefully produced, but also in the new fields where small producers of 20 to 30 bbl. were not neglected but were developed into steady commercial production. It has been generally known that in several districts on the Apsheron Peninsula and its immediate vicinity small shallow production was available over fairly large areas from thick sand bodies, insuring long life of the wells, but such production was not being developed because large gushers were obtainable in other fields of the district.

Northeast Caucasus (*Grozny*).—Production in the Grozny district further declined last year to 23,310,000 bbl., 64,000 bbl. per day, or to the lowest figure since 1927–28 operating year, when 25,900,000 bbl. was produced. The production of the two older fields of the Grozny district, the Old and the New (October group), dropped to about 18,000,000 bbl. during the past year, a decline of 68.15 per cent, as compared with the production from these two fields in 1931, when they produced together 56,500,000 bbl. In the new Grozny fields (October group) the plan of production was fulfilled to the extent of 99.6 per cent, the daily production at the end of the year averaging 40,600 bbl. per day. In 1935 the same tendency of greater attention to old small pumping wells that characterized the developments in Azerbaijan during the past year was also noted in the New Grozny field, and during the first half of the year 23 old wells were brought back into production by repairs, and produced

350,000 bbl. as compared with production of 553,000 bbl. from all new wells completed in that field during the same period of time. The Old Grozny field fulfilled its plan only to the extent of 33.9 per cent, owing entirely to the lack of mechanical supplies for the necessary repairs and for equipping the old wells for pumping. The Malgobek field, which is now two years old, produced 97.1 per cent of its 1935 assignment, its daily production rising from 5600 bbl. in January of 1935 to 22,400 bbl. per day at the end of the year. It is planned to produce from the Malgobek field about 8,000,000 bbl. in 1936. Several unimportant discoveries and extensions of questionable value were reported during 1935, none of which appeared to give promise for developing large production immediately. It is believed that on the whole the Grozneft spent too much effort and time in drilling to the deeper highly faulted formations, which as yet have not been proved either prolific or extensive.

Northwest Caucasus (*Maikop*).—The Kuban-Maikop area of the northwest Caucasus produced in 1935 some 8,340,000 bbl., 23,000 bbl. per day, or not much in excess of its 1934 production of 6,570,000 bbl. No developments or discoveries of particular importance were reported from Maikop, even though it is one of the most promising territories in Russia, hence it may be presumed that the management of this district continued to lack satisfactory technical and financial support. This indifference of the central authorities to the development of the most strategically located oil fields in Russia, which can be easily connected to the large southern centers of domestic consumption and which are near the export ports of the Black Sea, is very difficult to explain, though strategical considerations of developing reserves of crude oil and refining centers further inland, away from possible danger in case of war, probably has been an important and sound consideration in preferring the active development of the Oural fields.

Oural-Permian Basin (*Bashneft*).—The most important development in the Soviet Union within the last two years took place on the western slope of the Oural Mountains, where in the Bashkir steppes near Sterlitamak a second major base of crude-oil production and refining was being built. The strategic importance of this district to the Soviet Government in war or peace is immense. Sterlitamak district and its nearest large city, Ufa, only 80 miles away, is on and near four trunk railroad lines leading from European Russia to both Siberia and Turkestan. In transporting gasoline and other products to the Far East, railroad haulage of some 1500 miles will be saved, while the area is also nearer to the western frontiers by some 500 miles. The new district is within 200 to 400 miles from several large new industrial centers of the Soviet Union. Hence the Soviet Government is proceeding rapidly not only with drilling and exploration development of the area, but also with the construction of a modern refinery at Ufa, the construc-

tion contract for which has been awarded to the Alco International, a subsidiary of the American Locomotive Co. Because of the strategic location of the area in case of war, the new refinery will particularly specialize in the manufacture of aviation gasolines.

The oil production in the Oural-Permian Basin was first discovered in April of 1929, when a small well was completed at Chusovo, near Perm, about 350 miles north from Sterlitamak. After an extensive drilling campaign the limestones of this district were proved to be insufficiently porous and the development of Chusovo has been at this time practically discontinued. The first wells were completed at Ishimbaevo in April of 1932, and, considering the distance of the new discovery from the old oil-producing centers of Russia, its development proceeded rapidly. In 1933, three wells produced 16,000 bbl., while 52,000 ft. was drilled; in 1934, thirteen wells produced 438,000 bbl. and 80,000 ft. was drilled; and in 1935 twenty-six wells produced 2,840,000 bbl. and 145,000 ft. was drilled. The 1936 program anticipates production of 7,000,000 bbl. and drilling of 135,000 ft. in the producing fields and of 95,000 ft. in exploratory work. Early in 1936 there were 70 oil wells in Ishimbaevo, averaging in depth 2550 ft., of which, however, production was derived from only 26 naturally flowing wells while 44 inactive wells were awaiting equipment for mechanical lifting. The potential production of the field at this time appears to be around 30,000 to 35,000 bbl. per day, the production currently being limited by the transportation facilities. The completion of the refinery at Ufa and the connection of Ishimbaevo to Ufa by the pipe line will probably allow the production from this field to be increased to about 50,000 bbl. per day, or some 18,250,000 bbl. per year, within one year. Currently the crude oil from Ishimbaevo is transported in tank cars to the Saratoff refinery on the Volga River, a distance of about 430 miles. Eleven favorable structures similar to Ishimbaevo have been uncovered in the Sterlitamak district and several of these are scheduled to be tested extensively during 1936. Geological exploration included surface work, magnetic and gravimetric surveys.

The Sterlitamak fields are still handicapped somewhat by: (1) insufficiency of competent subordinate technicians and geologists, since there is a definite tendency in Russia today to retain men in the areas where they have been trained and hence only the young and inexperienced are sent into the new districts; (2) insufficiency of supplies; and (3) as already indicated, insufficiency of outlet for the crude oil. In February of 1936 the daily production was increased to about 16,000 bbl., but the railroads were able to take care of only about 8000 bbl., which resulted in an accumulation of about 500,000 bbl. in storage in the field and necessitated the shutdown of a number of wells. It is anticipated, however, that the present situation will be corrected during 1936 and Sterlitamak will become a major oil-producing and refining district of the Soviet Union.

Emba.—The great distances from the Emba district to all supply depots, to known fields and to large industrial centers, as well as complete absence of satisfactory transportation facilities, continue to greatly handicap the development of the Emba district, though potentially it is recognized as one of the most important in the country. In 1935 about 1,700,000 bbl., 4700 per day, were produced in Emba, or at a level not exceeding the pre-war production, when 1,820,000 bbl. was produced in 1916. The actual proven reserves of the Emba district are currently estimated at 31,500,000 bbl., while the probable reserves based upon the calculations of the number of possible salt domes in the Emba district, figured on the basis of one dome to 150 sq. miles, are calculated at a fantastic figure for this stage of the development. This is more particularly true because, while comparison is drawn between the Emba district and the Texas Gulf Coastal district, there are radical differences between the two. The most unfavorable aspect of the Emba salt domes as compared with the domes of the Texas belt is that the salt domes in Emba are faulted far more than the Texas domes, thus making prospecting for oil in the Russian salt domes far more difficult than in the United States. There remains a possibility that the crude oil reserves of the Emba salt domes are much greater on the flanks of the domes and at great depths where they are less disturbed by faults, but this remains to be proved in the future.

During the past year the Emba fields were connected by pipe line with Orsk, where a refinery is being constructed at this time. While quantitatively the Emba production probably will remain very small for many years to come, more particularly because of the developments in Sterlitamak, qualitatively very high-grade products are available in the new Emba fields, where, for instance, lubricating oil derived from Iskin crude tests 103 as compared with 100 for Pennsylvania lubricating crudes and 60 for lubricating crudes from Apsheron Peninsula fields; also, straight-run gasoline produced from Koschagil crude oil tests 76.5 octane as compared with 60 in Grozny and 70 in Baku.

Other Fields.—There were no developments of particular importance either in Turkestan or on Sakhalin Island, developments on the latter probably being held up in consideration of the political crisis in the Far East.

Drilling

The drilling technique of Soviet Russia improved appreciably over the preceding year but still the average time of drilling was well below the current American practice, though some drillers made amazing individual records. About 600 drilling rigs are in continuous operation in the Soviet Union, and have accounted for 4,123,000 ft. in 1934 and

4,920,000 ft. in 1935, while the 1936 plan calls for drilling of around 7,000,000 ft.

The speed of drilling, particularly stressed at this time by the Soviet oil industry, has been increased considerably in the last three years: in Baku the average speed per rig per month was increased from 550 ft. in 1933 to 970 ft. in 1935; in Grozny in the same period of time from 462 ft. to 890 ft.; in Maikop from 407 to 1260 ft.; in Sterlitamak from 586 to 930 ft.; and in Emba from 300 to 725 ft. Individual records of some drillers have approached 4000 ft. per rig per month, while it is anticipated that 5000 ft. per rig per month will be achieved by some men in 1936. The Stakhanoff movement, which implies high specialization of all men in a certain part of the whole work and also implies a concentrated effort of achievement, has been of great importance in improving the actual showing in drilling operations in the Soviet Union. By comparison, in pre-Stakhanoff days the driller was responsible, paid individual attention to and attended to every phase of drilling from looking after boilers and pumps to actual drilling, which, of course, necessitated periodical shutdowns of actual rotating, while at this time various men on the tower are trained to look after the details. Also, during the past year the problem of drilling straight holes was successfully solved, though limitations of hole deviation in Russia today are in the order of 7° as compared with 3° to 4° in the United States.

An important factor in improving the efficiency of labor was the very considerable increase in wages and the better living conditions of the workers in all branches of the oil industry, contemporaneous with the general easing up of living conditions in Russia. One of the features of the Stakhanoff movement is the piece-work remuneration of labor. For example, a tool pusher, who was receiving from 1000 to 1500 roubles per month for averaging 400 to 500 ft. per rig per month, increased his earnings to 2300 roubles for averaging about 700 ft. per rig per month, while future increase to 1500 ft. carried with it an increase in wages to 6500 roubles, provided the work done was of good quality and was performed economically. Corresponding increases in wages are carried down to all the men on the rigs as well as in refinery work, exploration, production, et cetera.

Refining

The refinery branch of the Russian oil industry also registered some qualitative improvements, even though total runs to stills of 146,705,000 bbl. in 1935 did not greatly exceed those of 1934, when 145,141,000 bbl. was processed. The plan for 1936 anticipates a very considerable improvement both in quality and in quantity of the refining branch of the industry. It is planned to run to stills in 1936 some 175,800,000 bbl.,

or an increase of 19.8 per cent, such increase being made possible by new construction, inclusive of the addition of several cracking stills.

In 1935, the production of gasoline was 26,400,000 bbl., or 18 per cent of the total runs, and of this total 9,500,000 bbl. was derived from cracking operations. In the previous year 23,700,000 bbl. of gasoline was produced, 16.32 per cent of the total runs, and of this 7,500,000 bbl. was secured from cracking operations. The 1936 plan calls for production of 35,300,000 bbl. of gasoline, of which 13,500,000 bbl. will be derived from the cracking stills, indicating a 20.10 per cent gasoline recovery in terms of total runs to stills. In 1935, the production of kerosene was 35,400,000 bbl., as compared with 34,800,000 bbl. produced in 1934, and the 1936 plan calls for 44,000,000 bbl. The total present modern refining capacity of Soviet Russia is not much in excess of 160,000,000 bbl. per year, though additional construction is bringing this total capacity to about 175,000,000 bbl. within the current year, which would suggest that the plan calling for refining of 175,800,000 bbl. in 1936 will not be fully fulfilled and that the expectation is for around 160,000,000 bbl. to 165,000,000 bbl. during the coming year. New refinery construction, which was held up pending the decision as to where large plants should be located, is now taking place along the Volga River and near Ufa, these locations being ideal both in consideration of the available supply of crude oil via river tankers and in consideration of the proximity of these refineries to the large industrial centers of Russia, as well as their distance from the international boundaries in case of war.

Domestic Demand and Exports

The Soviet Union probably consumed about 125,000,000 bbl. of petroleum products in 1935, while it exported about 22,000,000 bbl., thus indicating a 15.75 per cent increase in domestic consumption and a 21.4 per cent decrease in the exports, which was due entirely to the very rapidly increasing domestic demand. The unusually large increase in domestic consumption of gasoline is due to the very rapid growth of the use of automobiles, trucks and tractors. In 1930, there were in operation in the Soviet Union 26,500 automobiles and trucks and the total horsepower of tractors amounted to 746,000, while in 1935 there were more than 200,000 automobiles and trucks and the tractor horsepower in use is now more than 5,000,000. The industrial plans for 1936 call for an additional construction that will increase the number of automobiles and trucks at the end of 1936 to 325,000 units and will increase the horsepower of tractors in use to 6,000,000, these figures not including military equipment. A very interesting comparison can be made in the use of motorized equipment in the United States and in the Soviet Union: in the United States there is a total of about 24,000,000 motorized units, about

13 per cent consisting of trucks, and the annual consumption of gasoline per unit is 15.8 bbl., while in the Soviet Union, with the total number of motorized units about 200,000, of which 82 per cent are trucks, the annual consumption of gasoline per unit is about 92 barrels.

The problem of distribution of petroleum products for domestic consumption on a large scale and over vast distances of Russia presents at this time one of the more difficult problems of the Soviet Union, and 1936 will probably see extensive construction of small storage facilities throughout the country, so that the country can be supplied with sufficient reserves of gasoline, kerosene and other vital petroleum products.

The export of petroleum products from the Soviet Union continued, as already indicated, to decline both in volume and in value. The decline in the values accelerated during the past year because the principal reduction in exports was due to the decline in the shipments of gasoline, the most valuable product, while the exports of other products continued with but slight changes. Germany continued to be the principal market for the Soviet products, followed by France, British Empire, Italy, Spain, Japan, Sweden, Belgium, Denmark, etc.

Conclusions

The year 1935, on the whole, was a very satisfactory one in the Russian oil industry, and might well be the starting point of the oil industry built along modern lines, which will be able to supply the very rapidly increasing domestic demand. It is anticipated that the 1936 plan calling for production of 200,000,000 bbl. will be fulfilled, but it is not thought probable that over 160,000,000 to 165,000,000 bbl. of this total will be refined; the balance in heavier crude oils will probably be used as fuel oil.

The year 1936 should witness the discovery in Russia of several major oil fields and should also see the commercial development on a large scale of new fields recently discovered.

Petroleum Development in Venezuela during 1935

By C. A. Baird*

(New York Meeting, February, 1936)

With the exception of eight wildcat completions, which were unsuccessful and abandoned, all of the 1935 new drilling was performed in the proven fields. As of Dec. 31, 1935, 22 drilling rigs were in operation, of which 9 were at wildcat locations and the remainder were being used in new drilling in proven fields; in addition, 25 workover rigs (exclusive of cleanout rigs) were operating, all in the major fields.

Table 1.—*Comparison of* 1934 *and* 1935 *New Completions*

Year	Oil Wells	Gas Wells	Dry or Junked and Abandoned	Total
1934	217	3	18	238
1935	170	2	17	189
Difference	47	1	1	49 Decrease

Table 2.—*Location of Rigs, as of December* 31, 1935

Field	New Drilling	Workover	Wildcats	New Drilling	Workover
La Rosa Area	1	4	State of: Anzoategui	2	
Lagunillas Field	3	15	Falcon	3	
Mene Grande Field	1	3	Monagas	2	
Rio Tarra Field		1	Sucre	1	
Cumarebo Field	1	1	Zulia	1	
Quiriquire Field	6	1			
Pedernales Field	1		Total	9	
Total	13	25	Total, fields and wildcats	22	25

Production of Crude Oil.—Notwithstanding the considerable decrease in new completions during 1935 as compared with 1934, crude production mounted to a new high of 148,893,225 bbl., clean oil at 60° F., representing an increase of 12,532,579 bbl. over the previous record year, 1934, total of 136,360,646 bbl. This increase was due: (1) to the flush production

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obtained from new drilling at Lagunillas and Quiriquire; and (2) to the yield from 307 new pump units, of which 283 were installed in the Maracaibo Lake Shore (District of Bolivar, State of Zulia) fields. The success attending the rapid expansion of pumping facilities was in large part due to the reworking of many old dead wells.

The daily average for the year was 407,927 bbl.; the monthly daily averages varied from a low of 364,535 bbl. (March) to a high of 426,218 bbl. (October).

During December, 1934, Venezuelan and Lagunillas field "clean" crude oil production reached cumulative totals of 1,000,000,000 and 500,000,000 bbl., respectively.

Natural Gasoline.—Recovery of natural gasoline for 1935 has been nominally estimated at 500,000 bbl., compared to the 1934 total of 516,064 bbl. Most of this product is blended with crude oil.

TABLE 3.—*Summary of Production and Exports by Years, Venezuela*
Barrels of 42 U.S. Gallons

Year	Crude-oil Production[a]	Percentage of World Production[c]	Exports[d]
1917	222,506	0.04	57,000
1918	361,974	0.07	144,000
1919	254,727	0.05	14,000
1920	518,484	0.07	
1921	1,476,243	0.19	998,000
1922	2,863,918	0.34	1,813,000
1923	3,692,395	0.36	3,334,000
1924	9,078,763	0.90	8,554,000
1925	20,213,210	1.89	18,927,000
1926	37,003,887	3.37	33,743,000
1927	62,981,403	4.99	57,303,000
1928	105,218,809	7.95	100,659,000
1929	136,316,757	9.18	130,045,000
1930	135,483,584	9.62	137,745,000
1931	116,929,758	8.54	116,683,000
1932	116,428,728	8.92	114,567,000
1933	118,317,794	8.33	120,183,961
1934	136,360,646	9.16	133,882,514
1935	148,893,225[b]		145,192,839[b]
Total to date........	1,152,616,811		1,123,745,314

[a] Revised figures, clean oil at 60° F.; includes natural gasoline recovery from El Mene field.

[b] December partly estimated.

[c] Derived from table by V. R. Garfias and R. V. Whetsel [*Oil Weekly* (Jan. 28, 1935) 47] by substituting corrected Venezuela data for the years 1927–1934, inclusive.

[d] A mixture of clean and gross oil at 60° F.; a total of crude oil, natural gasoline and refined products.

Exports.—Venezuelan oil exports, consisting of crude and refined products, together with a small quantity of natural gasoline, amounted to 145,192,839 bbl., an increase of 11,310,325 bbl. over the 1934 total. Our export records are at present a mixture of gross (i.e., without correction for bottom settlings and water) and clean oil at 60° F. The export daily average for the year was 397,789 barrels.

TABLE 4.—*General Destination of Venezuelan Oil Exports*

Year	To N.W.I.	To U.S.A.[a]	To Others	Total
1934	106,296,086	22,253,892	5,332,536	133,882,514
1935	114,977,910	23,147,173	7,067,756	145,192,839
Difference	8,681,824 Increase	893,281 Increase	1,735,220 Increase	11,310,325 Increase

[a] All crude oil.

TABLE 5.—*Comparison of Foreign Distribution of Venezuelan Oil*[a]

Year	Destination	Crude	Refined Products	Total Export Movement
First six months of 1934	To U.S.A.	11,211,912	6,205,290	17,417,202
	To Others	4,349,167	42,212,988	46,562,155
	Total	15,561,079	48,418,278	63,979,357
First six months of 1935	To U.S.A.	12,125,419	8,858,353	20,983,772
	To Others	4,312,349	43,042,249	47,354,598
	Total	16,437,768	51,900,602	68,338,370
Difference	To U.S.A.	913,507 Increase	2,653,063 Increase	3,566,570 Increase
	To Others	36,818 Decrease	829,261 Increase	792,443 Increase
	Total	876,689 Increase	3,482,324 Increase	4,359,013 Increase

[a] Sum of Venezuelan exports to points other than the Netherlands West Indian Islands of Curaçao and Aruba and of N.W.I. exports of oil originating in Venezuela; close approximation.

Crude Storage.—At the end of 1935 crude oil in storage amounted to 6,469,348 bbl., as compared to 4,825,385 bbl. at the end of 1934, an increase of 1,643,963 bbl. Steel tankage employed for crude storage totaled 16,226,440 bbl. as of Dec. 31, 1935.

Comments by States and Fields

No new fields were discovered during 1935, but substantial extensions were made to the exploited portions of the La Rosa area (particularly the localities known by the field names of La Rosa and Punta Benitez), and the Lagunillas, Mene Grande and Quiriquire fields. Amacuro No. 1 of the Pedernales field was a notable completion of the year, having resulted in a 750 to 1000-bbl. flowing well; previous drilling in this Eastern Venezuela locality had yielded poor results.

Table 6 shows cumulative crude production, a comparison of 1934 and 1935 crude production and general information, by fields. Table 7 gives in detail the status of all wells drilled for oil and gas as of Dec. 31, 1935. The accompanying map shows the state boundaries north of the Orinoco and Apure Rivers, the location of the active and inactive fields and the deep-water terminals of the exporting companies.

The Bolivar coastal fields are operated by only three companies, whereas the other Venezuelan fields are owned and operated by individual companies, an arrangement that has permitted orderly development and efficient exploitation.

State of Zulia (*Lake Maracaibo Basin*)

La Rosa Area.—This term is applied to the three formerly separate localities of Ambrosio, La Rosa and Punta Benitez, which have been gradually joined by drilling into one common productive field. Despite the 42 completions and an increase of 82 pump installations during the year, production decreased 1,383,118 bbl. under the 1934 total. However, the yield no doubt could be increased by applying artificial lift facilities to the large number (288) of dead inactive wells. Oil sands (19° to 29° Bé.) present in the marine Upper Oligocene strata have furnished nearly all of the recovery to date, and with the exception of one locality (southern Ambrosio), no water difficulties have developed. As in the remainder of the Bolivar lake shore fields, the Eocene surface (unconformity) is usually the final depth objective. An impressive future oil reserve is contained in a 300 to 450-ft. zone of tar sands (14° to 18° Bé.), which directly overlies the Oligocene; this zone has a wide areal extent and at present is being exploited in only a few wells. The landward limits of the La Rosa area oil zones have been fairly well defined, but their lakeward limits have not yet been determined.

Tia Juana Field.—This field remained inactive throughout the year, as in 1934. The La Rosa area tar zone is the important productive level of this field and here consists of a thick body of soft, porous, oil-saturated sands. The position of edge water (alkaline) has been noted in a few of the exploratory wells. This field has not yet been exploited and to date its limits have been but partially determined. Needless to say, it

FIG. 1.—LOCATION OF OIL FIELDS AND DEEP WATER TERMINALS IN NORTHERN VENEZUELA.

comprises an important future reserve of heavy oil. Additional exploration will be carried out in 1936.

Lagunillas Field.—The 1935 production of this field accounted for 54.5 per cent of the Venezuelan annual total, representing an increase of 8,796,682 bbl. over its 1934 production. The cumulative total of the field likewise accounts for 50.6 per cent of the Venezuelan cumulative total. New completions during the year totaled 50, of which only four were unsuccessful; in addition, each of the three operating companies maintained several rigs that were solely engaged in reworking old wells as

TABLE 6.—*Cumulative Crude Production, Venezuela, Comparison of*

Field	District	State	Age in Years[3]	Area Proven Acreage[4]	Crude Production, Clean Oil at 60° F., Bbl. of 42 U.S. Gal.	
					To End of 1935	During 1934
La Rosa area[1]	Bolivar	Zulia	13	25,000	268,579,155	23,031,565
Tia Juana	Bolivar	Zulia	8	5,000	29,061	
Lagunillas	Bolivar	Zulia	10	35,000	582,725,058	72,353,788
Bachaquero	Bolivar	Zulia	6	5,500	35,189	
Total lake fields				70,500	851,368,463	95,385,353
Mene Grande	Sucre	Zulia	21	5,750	155,303,142	15,012,576
Misoa	Sucre	Zulia	18	85	266,909	
Rio Tarra	Colon	Zulia	15	1,000	23,533,464	3,643,762
Los Manueles	Colon	Zulia	6	250	12,921,374	1,682,464
Rio de Oro	Colon	Zulia	21	390	50,827	
La Paz	Maracaibo	Zulia	11	250	3,382,039	227,160
La Concepcion	Maracaibo	Zulia	11	900	16,986,858	1,737,821
Totumo	Perija	Zulia	8	300	149,452	
El Mene	Buchivacoa	Falcon	13	850	19,691,497[5]	788,179[5]
Media	Buchivacoa	Falcon	5	40	2,027,069	207,212
Hombre Pintado	Buchivacoa	Falcon	8	150	184,876	16,267
Las Palmas	Buchivacoa	Falcon	8	50	172,418	
Urumaco	Democracia	Falcon	8	100	235,989	
Cumarebo	Zamora	Falcon	4	440	13,890,509	3,860,661
El Mene de Acosta	Acosta	Falcon	7	75	760,149	46,732
Quiriquire	Piar	Monagas	9	10,000	49,733,311	13,721,766
Orocual	Piar	Monagas	3	975	19,577	16,884
Guanoco	Benitez	Sucre	11	150	1,718,150	
Pedernales	Terr. Delta	Amacuro	3	20	65,011	13,809
				92,275	1,152,461,084	136,360,646
Wildcats[2]		Anzoategui				
		Falcon			10,904	
		Merida				
		Monagas			6,068	
		Sucre				
		Trujillo			15,500	
		Zamora				
		Zulia			123,255	
		Terr. Delta Amacuro				
Grand total					1,152,616,811	

[1] Includes Ambrosio, La Rosa and Punta Benitez fields, which drilling has joined into one area.
[2] Includes some oil wells, such as Amana, Netick, Curazao, Cacuz, Zulod (State of Zulia); Monte Claro (Falcon); and Pauji (Trujillo), which have not yet been developed into commercial pools.
[3] Counting from date of first recorded production.
[4] The majority of Venezuelan fields are not fully defined to date.
[5] Includes all El Mene natural gasoline production, which was blended with crude; approximately 53,700 and 50,000 bbl., 1934 and 1935, respectively.

a means of maintaining and increasing pump production. Two hundred and one new pump units were installed, bringing the field total to 411.

The productive levels are correlated with the La Rosa area tar zone and comprise an interval of 200 to 300 ft. over a large part of the field; this interval may be divided into at least two oil zones, of which the upper yields oil of 14.0 to 16.5° Bé. and the lower (and most important) 17.5 to 21.0° Bé. In the approximate southern two-thirds of the field the lower zone directly overlies the Eocene surface and is believed to pinch out against the unconformity in an updip direction. Both zones are

1934 *and* 1935 *Crude Production and General Information, by Fields*

Crude Production, Clean Oil at 60° F., Bbl. of 42 U.S. Gal.		Oil, Gravity Bé. A.P.I.		Average Depth of Wells to 12–31–35, Ft.	Producing Rock				Deepest Zone Tested to 12–31–35, Age
During 1935	Daily Average Dec., 1935	Present Range	Present Approx. Shipping Average		Age[g]	Character[h]	Porosity[i]	Structure[j]	
21,648,447	64,085	14.0–29.0	23.4	2,360	MioL-OligU	Ss-H	Por	Af-MU	Eoc
		15.0–17.0		2,845	MioL	Ss	Por	A	OligU
81,150,470	211,125	11.0–21.0	17.3	3,360	MioL	Ss	Por	Af-MU	Top 200′ Eoc
		10.4–18.4		4,525	MioL	Ss	Por	A	MioL
102,798,917	275,210								
15,510,285	53,537	13.8–29.1	20.8	2,383	Mio-Eoc	Ss and S	Por	A(N)F	Eoc
		15–22			Eoc	S	Por	A(N)F	Eoc
3,948,038	11,019	23.1–36.7	33.2	2,310	Eoc	S	Por	AF	Cre
1,183,646	2,701	14.7–35.5	33.0	4,020	Olig-Eoc	S	Por	AF	Eoc
		25.6–37.7		1,627	Eoc	S	Por	A	Eoc
171,396	424	24.0–27.8	27.2	1,307	EocL	S and LS	Por	Af	CreU
1,428,585	3,617	28.2–40.6	35.6	1,718	Eoc	SH	Por	Af	Eoc
		19.7–21.1		2,359	?	Igneous[6]	Fis	MF	Pre-Cre?
743,299[5]	1,870	35.5–36	36	1,000	MioU-OligU	S	Por	AF-U	Eoc?
104,208	310	35.5–36	36	3,500	MioL	S	Por	MF-MU	Eoc
16,381	49	28	28	1,600	Mio-Olig	S	Por	AF	Mio-Olig
7,687		33.6–35.2	34.4	2,750	Olig	S	Por	Af	Eoc
		37.0–38.8		3,383	Mio		Por	AF-U	MioL
3,021,580	7,415	50.2–50.4	50.3	1,650	Mio	S	20–30%	AF	MioL
38,723	97	41–50	45		OligU	S	Por	Af	OligL
19,874,565	59,879	12.0–20.8	18.4	3,000	MioU-Pli	Ss	10–20%	MU	Olig; Cre
		12–13		3,000	MioU-Pli	Ss	Por	MU	Olig
		10.5		1,298	Cre	H	Fis	AF	CreU
45,915	18	15.7–20.8	20.5		Mio	Ss	Por	AF	Mio
148,893,225	416,146								

[6] Fractured porphyritic trachyte.
[g] Footnotes to column headings and explanation of symbols are given on page 215.

experiencing edge-water invasions, of which that of the lower zone is the most serious; because of the small gravity contrast between the alkaline water and the heavy oil, tight emulsions are formed, requiring treatment of the wet oil.

A "tar" zone about 400 ft. thick, containing oil of 11° to 12° Bé. is also present in the southern two-thirds of the field; the top of this zone is approximately 1000 ft. above the Eocene surface. In view of its thickness and wide extent, this zone contains a vast quantity of tar crude.

Considering the present productive levels, exploratory wells have roughly outlined a proven area of approximately 35,000 acres, of which some 17,000 have been drilled and are under exploitation.

Bachaquero Field.—This field remained inactive throughout 1935 but additional exploration is expected during 1936. As determined to date, the important productive level is equivalent to the Lagunillas tar zone: it has a thickness of 235 to 300 ft. and yields 10.4° to 13.2° oil. Two tests have been completed in this level, resulting in 1000 to 2000 bbl. daily production per well. A second oil level of apparent small areal extent underlies the tar zone and yields oil of 17° to 18.4° Bé. in quantities of 150 to 700 bbl. daily per well.

The La Rosa area and the Tia Juana, Lagunillas and Bachaquero fields are commonly grouped together as the Bolivar coastal or Maracaibo Lake shore fields. Table 6 shows that their 1935 production comprised 69 per cent of the country's annual total.

Mene Grande Field.—There were 32 completions in 1935, of which two were failures. Production increased 497,709 bbl. over the 1934 total of 15,012,576 bbl. It dropped to fourth rank among the producing fields, having yielded third place to the Quiriquire field. There are two oil levels, of which the most important is a thick zone present over the entire field, overlying Eocene shales; this yields heavy oil of 13.8° to 22.6° Bé., most of which averages 17.0° Bé. The second level is found in Eocene sandstones in a portion of the field and yields 28° to 29.1° Bé. oil. One of the Eocene wells has produced slightly more than 11,275,-000 bbl. as of Dec. 31, 1935, and continues flowing about 4250 bbl. daily. The nearest approach to this remarkable natural flow performance among the other Venezuelan fields has been a 3,300,000-bbl. well in the southern part of the Lagunillas field. Edge waters have been noted in both levels.

Rio Tarra and Los Manueles Fields.—There were no completions in these two fields. Rio Tarra production increased 304,276 bbl., whereas that from Los Manueles decreased 498,818 bbl., resulting in a net decrease of 194,542 bbl. from the two areas, as compared to 1934.

La Concepcion and La Paz Fields.—No new drilling was completed during the year under review. Production declines of 309,236 and 55,764 bbl., respectively, under the 1934 totals were noted. The productive limits of either field have not been determined. In 1933, the date of

last drilling, a deeper level was discovered in Concepcion No. 101 yielding about 900 bbl. initial daily flow of 42.5° Bé. oil; no other wells have been drilled to the new zone.

Other Zulia Fields.—The two wells of the Netick field, District of Mara, remained closed in; one of these is a small pumper, whereas the other has a daily natural flow potential of 500 bbl. 27.5° Bé. oil. The Totumo field, District of Perija, likewise is closed in, with a natural flow potential production of 2300 bbl. daily.

Wildcats.—No wildcats were completed in the Lake Basin area; however, a deep test (Icotea No. 1 of the Lago Petroleum Corporation) into Eocene strata was started during November, 1934, in the center of Lake Maracaibo, nearly 6 miles west of the Ambrosio field. As of the end of the year, the depth was 7852 ft. The Covir No. 1 wildcat of the Venezuela Gulf Oil Co., District of Urdaneta, completed in 1930 with a total depth of 8323 ft., remains the deepest well in Venezuela, as of Dec. 31, 1935, but is expected to yield its ranking to Icotea No. 1 early in 1936.

State of Falcon

El Mene and Media Fields.—No additional drilling was performed and production decreases of 44,880 and 103,004 bbl., respectively, under 1934 were recorded. Recovery from both fields is entirely by artificial methods.

Hombre Pintado Field.—One well of this small field was pumped throughout the year.

Cumarebo Field.—Thirteen wells were completed in 1935, of which two were gas wells and the remainder oil producers. Production continued to decline from the peak level of 1933, there being a decrease of 839,081 bbl. as compared to 1934. The field is small and accumulation in the several oil levels has been influenced considerably by faulting.

El Mene de Acosta Field.—Only one completion, a dry hole, was made during 1935 and production continued to decline.

Other Falcon Fields.—Las Palmas and Urumaco fields remained closed in with natural flow potentials of 800 and 2000 bbl. respectively.

Wildcats.—Wildcats in 1935 in Falcon were as shown at the top of page 514.

An old well, San Berjadin No. 3 of the Standard Oil Co. of Venezuela, in the District of Buchivacoa, was deepened from its original depth of 4389 ft. to 5426 ft. and abandoned during the year. La Guinea No. 1, of the British Controlled Oilfields, Ltd., in the District of Buchivacoa, which was drilled to 6841 ft. in 1934, remains suspended.

State of Anzoategui

Wildcats.—No wells were completed during 1935. At the close of the year, Venezuela Gulf Oil Company's Santa Rosa No. 1, in the north-

Company	Well Name	District	Spudded In	Com-pleted	Total Depth, Ft.	Remarks
British Controlled Oilfields, Ltd.	Mauroa-1	Buchivacoa	12– 5–34	1–11–35	6150	Dry hole. Abandoned.
Standard Oil Co. of Venezuela..	La Vela-5	Colina	9–29–34	1–23–35	5285	Dry hole. Abandoned.
Standard Oil Co. of Venezuela..	Isidore-1	Zamora	6–29–34	2–28–35	6847	Dry hole. Abandoned.
Standard Oil Co. of Venezuela..	Taguaqui-1	Zamora	12–22–34	6–25–35	6292	Dry hole. Abandoned.
British Controlled Oilfields, Ltd.	Vega Oscura-2	Buchivacoa	2–12–35		6651	Drilling in progress on 12–31–35.
Standard Oil Co. of Venezuela..	San Patricio-1	Zamora	7–17–35		7486	Drilling in progress on 12–31–35.

central part of the District of Freites, was fishing for stuck drill pipe with a total depth of 7213 ft.; also, preparations were being made to drill a test approximately six miles southeast of Santa Ana village, in the District of Aragua. In the District of Independencia, La Canoa No. 1 of the Standard Oil Co. of Venezuela, was drilling at 3855 feet.

State of Monagas

Quiriquire Field.—With 41 completions, of which only one was unsuccessful, production increased 6,152,799 bbl. over 1934 to a new yearly high of 19,874,565 bbl., thereby giving this field third rank in the 1935 production. Daily average production per month varied from a low of 43,747 bbl. in March to a high of 62,136 bbl. in June, the annual average being 54,451 bbl., as compared to 37,594 bbl. for the year 1934. Production is obtained from a fairly thick zone of soft porous sands. Over the greater part of the field these sands unconformably overlie Oligocene black shale, but at the northern edge of the productive area, they contact Upper Cretaceous strata.

During the year a new export terminal for the loading of ocean tankers was completed and placed in service at Guiria on the south coast of the Paria Peninsula. Oil from Quiriquire is piped to Caripito, on the San Juan River, where the Standard Oil Co. of Venezuela has a loading terminal; it is then transported by barge or tanker to Guiria, a distance of approximately 91 land miles.

Orocual Field.—No drilling was performed, likewise no production was obtained in 1935. Of the seven wells drilled to date by the Standard Oil Co. of Venezuela, four have been abandoned as failures. The remaining three wells were originally completed as small producers of tar-grade oil; at present, one is closed in with a natural flow potential of 45 bbl., one is dead and one is classed as an idle pumper. These three wells, however, have "proved" a relatively large area, and for that reason, as well as future possibilities, the area has been given a field rank in this paper.

Wildcats.—The following wildcats were drilled in Monagas by the Standard Oil Co. of Venezuela:

Well Name	District	Spudded In	Com-pleted	Total Depth, Ft.	Remarks
San Juan-1........	Piar	12–18–34	10–29–35	5020	Dry hole. Abandoned
Caripito-1.........	Piar	4– 8–35	8–19–35	5137	Dry hole. Abandoned
El Lirial-1.........	Maturin	10– 3–35		4550	Drilling in progress on 12–31–35.
Temblador-1......	Sotillo	12–20–35		151	Drilling in progress on 12–31–35.

State of Sucre

Guanoco Field.—This field continued inactive throughout the year. The closed-in natural flow potential of 10 wells is estimated to be 1000 bbl. The production, which is of tar grade, apparently issues from fractures in Upper Cretaceous shale, since no sandy strata have been noted. Approximately 1100 acres of the surface of the field is covered with a 6-ft. layer of asphalt, which has been mined extensively in past years, but there has been little activity since 1931.

Oil development has been carried on by the Bermudez Company and the asphalt mining by the New York and Bermudez Company; both concerns are subsidiaries of the General Asphalt Co. In April, 1935, the holdings of both companies were sold to new interests but to date operations have not been resumed.

Wildcats.—Wildcats in Sucre in 1935 (Standard Oil Co. of Venezuela) were as follows:

Well Name	District	Spudded In	Com-pleted	Total Depth, Ft.	Remarks
Morrocoy-1.................	Benitez	11– 7–34	3–26–35	5096	Dry hole. Abandoned.
Morrocoy-2.................	Benitez	5–28–35	8–12–35	3835	Dry hole. Abandoned.
San Juan-2.................	Benitez	11–27–35		2811	Drilling as of 12–31–35.

Territory Delta-Amacuro

Pedernales Field.—Two completions were made in 1935; namely, Pedernales No. 4 on Feb. 20, abandoned as a dry hole at 3756 ft., and Amacuro No. 1 on Aug. 11, which resulted in a well flowing 750 to 1000

TABLE 7.—*Status of Wells Drilled for Oil or Gas*

	Well Completions 1935				Total Completions to 12-31-35				Status of Completed Wells as of 12-31-35											Incomplete and Drilling Wells 12-31-35	
									Total Abandoned Wells[1]	Total Temporarily Abandoned[2]	Producing Oil Wells				Inactive Oil Wells						
	Oil	Gas	Dry or Junked and Abandoned	Total	Oil	Gas	Dry or Junked and Abandoned	Total			Nat. Flow	Air-gas Lift	Pumping	Total	Closed-in Nat. Flow	Repressuring	Idle Pumpers[3]	Dead	Total	Active	Standing
La Rosa area	41		1	42	1,036	1	40	1,077	40	54	123	67	416	606	24	26	38	288	376	1	
Tia Juana					10		2	12	2						9			1	10		
Lagunillas	46		4	50	803		8	811	17	10	168	93	367	628	13	1	44	98	156	2	1
Bachaquero					3			3							3				3		
Total lake fields	87		5	92	1,852	1	50	1,903	59	64	291	160	783	1,234	49	27	82	387	545	3	1
Mene Grande	30		2	32	269		10	279	17		54	90	2	146	9			107	116	1	2
Misoa					8		7	15	11									4	4		
Rio Tarra					68		12	80	12	1	6	1	17	24	1		1	41	43		3
Los Manueles					13		2	15	3		7	1		8				4	4		1
Rio de Oro					3		1	4	1						3				3		
La Paz					30		3	33	4		1	2	1	4	3		1	21	25		2
La Concepcion					101		1	102	1	1	3	3	66	72	8		13	7	28		
Totumo					12		1	13	2						8			3	11		
El Mene					196		89	285	145			43	55	98			3	39	42		
Media					15	1	12	28	13			4		4				10	10		
Hombre Pintado					4		1	5	2				1	1				2	2		
Las Palmas					9	2	2	13	2	1					2			6	8		
Urumaco					4		3	7	3						4				4		
Cumarebo	11	2		13	64	8	10	82	12		38		1	39	7	6		10	23	1	
El Mene de Acosta			1	1	41		40	81	68				13	13							

Table 7.—(*Continued*)

	Well Completions 1935				Total Completions to 12-31-35				Status of Completed Wells as of 12-31-35											Incomplete and Drilling Wells 12-31-35	
											Producing Oil Wells				Inactive Oil Wells						
	Oil	Gas	Dry or Junked and Abandoned	Total	Oil	Gas	Dry or Junked and Abandoned	Total	Total Abandoned Wells[1]	Total Temporarily Abandoned[2]	Nat. Flow	Air-gas Lift	Pumping	Total	Closed-in Nat. Flow	Repressuring	Idle Pumpers[3]	Dead	Total	Active	Standing
Quiriquire	40		1	41	134		10	144	15	2	84		20	104	6	4	2	11	23	4	
Orocual					3		4	7	4						1		1	1	3		
Guanoco					16		6	22	8						10			4	14		
Pedernales	2			2	3		3	6	4		1			1	1				1	1	
Wildcats:																					
State of: Anzoategui																				2	4
Falcon			4	4	2	1	57	60	58	1										3	1
Merida							6	6	6												
Monagas			2	2	2		13	15	15											2	
Sucre			2	2			4	4	4											1	
Trujillo					1		6	7	7												
Zamora							1	1	1												
Zulia					7	1	81	89	82						3			3	6	1	1
Terr. Delta Amacuro							6	6	6												
Total 1935	170	2	17	189	2,857	14	441	3,312	565	70	485	304	959	1,748	115	37	103	660	915	19	15
Total 1934	217	3	18	238	2,687	12	424	3,123	515	63	474	320	596	1,390	184	23	159	777	1,143	23	13

[1] Abandoned dry or junked holes and some oil and gas wells subsequently abandoned.

[2] Former productive wells which cannot be produced economically in present status and have poor possibilities of future recovery; awaiting final abandonment.

[3] Wells fully equipped for pumping, which are temporarily inactive by reason of awaiting cleanout or workover, surplus requirements, etc.

bbl. 20.8° Bé. oil. Of the six wells drilled to date by the Standard Oil Co. of Venezuela, four have been abandoned, either as dry holes or non-commercial wells. Heaving shale has been reported in some of the wells. The Miocene strata have been highly disturbed by faulting. At the close of the year Amacuro No. 2 was drilling at 218 feet.

Companies Producing Oil during 1935

The subsidiaries of the Standard Oil Co. of New Jersey—the Lago Petroleum Corporation and the Standard Oil Co. of Venezuela, produced 72,140,506 bbl., or 48.45 per cent of the annual total. The Lago corporation's oil came from the Maracaibo Lake shore fields; the Standard Oil Co. of Venezuela obtained oil from its solely owned fields, Las Palmas, Cumarebo, Quiriquire and Pedernales; it is also credited with the Creole Petroleum Company's share of oil from properties owned jointly with and operated by the Venezuela Gulf Oil Co. in the lake shore fields.

The Dutch Shell group, consisting of the Caribbean Petroleum Co., Colon Development Co. and Venezuelan Oil Concessions, Ltd. produced 57,634,408 bbl., or 38.71 per cent of the year's total. The first named of this group operates the Mene Grande field; the second, the Rio Tarra and Los Manueles fields; and the third, the La Paz and La Concepcion fields and its competitive properties in the lake shore fields.

The Venezuela Gulf Oil Company's production was obtained in the lake shore fields, accounting for 11.21 per cent of the 1935 total.

The British Controlled Oilfields, Ltd. operates the El Mene, Media and Hombre Pintado fields.

Companies Exporting Oil during 1935

The Caribbean Petroleum Co., the principal exporting company of the Dutch-Shell group, added two new shallow-draft tankers of 23,000 bbl. capacity each to its fleet during the year; this company also purchases and exports the oil produced by the British Controlled Oilfields, Ltd. The Canadian Eagle Oil Co., also of the Dutch-Shell group, continued its exports of oil produced by and purchased from companies in the lake shore fields.

A new tanker of 24,000 bbl. capacity was added to the Lago Petroleum Corporation fleet. A tanker of 45,000 bbl. capacity was transferred from abroad to eastern Venezuela, joining the fleet of the Standard Oil Company of Venezuela. No changes occurred in the fleet of the Venezuela Gulf Oil Company.

Geological and Geophysical Investigations

At the close of the year the following parties were active:

Geological.—A total of nine: four for the Standard Oil Co. of Venezuela, one for the Venezuela Gulf Oil Co. and one for the Venezuelan Petroleum

Co., all in eastern Venezuela; two for the Caribbean Petroleum Co. in the States of Zamora and Portuguesa and one in the District of Mara, State of Zulia.

Geophysical.—A total of six seismograph crews: two each for the Standard Oil Co. of Venezuela and Venezuela Gulf Oil Co. in eastern Venezuela; one for the Caribbean Petroleum Co. in the District of Maracaibo, State of Zulia, and one for the Lago Petroleum Corporation, preparing for work in the States of Falcon and Zulia.

Five torsion balance and one gravimeter parties: one for the Standard Oil Co. of Venezuela; three torsion balances and one Holweck gravimeter for the Caribbean Petroleum Co.; one combination torsion balance and magnetometer party for the Venezuelan Petroleum Co., all in eastern Venezuela.

Three magnetometer crews: one each for the Standard Oil Co. of Venezuela and the Venezuela Gulf Oil Co., as well as the above mentioned Venezuelan Petroleum Co. party, all in eastern Venezuela.

In addition to the above, a number of engineering parties are active, particularly in eastern Venezuela.

Activity in Lands

Two important trades of eastern Venezuelan acreage were completed during the year; one being the Standard Oil Co. of Venezuela's development contract with Pantepec interests, involving approximately 650,000 acres and a large expenditure for drilling; the other, the purchase by the Venezuela Gulf Oil Co. of Orinoco Oilfields, Ltd. holdings, involving approximately 1,000,000 acres.

The principal companies reduced their Venezuelan holdings approximately 1,000,000 acres during the year; in addition, the Venezuelan Government canceled delinquent concessions, amounting to nearly 12,000,000 acres.

A new Petroleum Law became effective July 1, in which the only important change as compared to previous laws is a provision permitting the Venezuelan Government to negotiate for bonuses and higher royalties in new concessions, without, however, changing the old base rate.

Acknowledgment

The author wishes to acknowledge his indebtedness to Messrs. Paul Adams, Hollis Hedberg and Fred Hulsmeier, of the Venezuela Gulf Oil Co., for their assistance in the preparation of this paper; also to Messrs. D. B. Williams, of the Caribbean Petroleum Co.; D. C. Porterfield, of the Lago Petroleum Corporation; John Brice of the Standard Oil Co. of Venezuela; Douglas Wood, of the British Controlled Oilfields, Ltd., and H. F. Finch, for statistical information.

Oil and Gas Development in Colorado in 1935

By C. E. Shoenfelt,* Member A.I.M.E.

(New York Meeting, February, 1936)

There were no important discoveries of either oil or gas in Colorado in 1935. There was, however, further development of the Price structure in southern Colorado and developments since the first of the year indicate that an important oil field may be in the making. The discovery of oil in Price structure was made by the Oil City Petroleum Co. late in November, 1934, in its No. 2 Garnett in the northeast corner of lot 3 in the SW.¼ of sec. 25-33N.-2E. This well developed a good showing of oil in Dakota sand at 970 ft. The hole filled up 15 ft. with 40° gravity oil overnight and after standing for several days the oil level was 400 ft. higher.

As a result of the discovery of oil by the No. 2 Garnett, three wells were drilled by the William E. Hughes Estate. Two of these wells had good showings of oil and may make good producers but it is doubtful whether they will produce the estimated capacity of 500 bbl. each with which they have been credited. Although the Hughes Estate wells have been completed for some time, they have not been given thorough production tests because of the isolated position of the field and lack of proper facilities.

The first well drilled by the Hughes Estate was located on the west side of the Navajo River on the downthrow side of a fault. It encountered water in the Dakota sand at 1285 ft. and was abandoned in green shales of the Morrison at 1405 ft. Well cuttings from the Dakota sand showed some evidence of once containing oil, so a location was selected for No. 2 Fee on the east side of the river and on the upthrow side of the fault.

Oil was discovered in Dakota sands in 1935 by Continental Oil Co. in its No. 3 Hoye, NW.NW.NE. of sec. 34-9N.-78W., on the South McCallum anticline in North Park, Jackson County, Colo., but on account of heavy flows of carbon dioxide gas under high pressure it has been impossible for the company to get an accurate gage of the oil production. The freezing action of expanding carbon dioxide makes the producing of the oil difficult and costly.

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Oil was discovered in 1927 in the Muddy sand on South McCallum anticline by Continental Oil Co. Its No. 1 Hoye, NW.SE.NE. of sec. 34-9N.-78W., was completed at 4875 ft. for an initial production of 50,000,000 cu. ft. of carbon dioxide gas and a few barrels of oil with a gravity of 45.8° A.P.I.

TABLE 1.—*Oil and Gas Production in Colorado*

Line Number	Field, *County*	Age, Years to End of 1935	Area Proved, Acres: Oil	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1935	Total Oil Production, Bbl.: During 1934	Total Oil Production, Bbl.: During 1935	Total Oil Production, Bbl.: Daily Average during Nov., 1935
1	Berthoud, *Larimer*	6	510		510	37,871	4,760	4,017	10
2	Boulder, *Boulder*	33	400		400	616,963	6,391	6,357	18
3	Florence-Canon City, *Fremont*	74	9,000		9,000	13,277,160	82,151	69,955	131
4	Ft. Collins, *Larimer*	12	400		400	2,018,311	38,132	26,544	57
5	Garcia, *Las Animas*	9		640	640				
6	Greasewood, *Weld*	5	200		200	414,835	36,487	26,981	60
7	Hamilton (Moffat), *Moffat*	12	400		400	5,045,088	162,746	150,703	328
8	Hiawatha, *Moffat*	8		3,180	3,180				
9	Iles, *Moffat*	11	600		600	4,181,647	514,947	1,027,901	2,743
10	Mancos Creek, *Montezuma*		40		40	3,598	606	724	2
11	Model, *Las Animas*	7		2,000	2,000				
12	Rangely, *Rio Blanco*	16	320		320	403,094	31,270	29,746	67
13	Tow Creek, *Routt*	11	200		200	1,408,414	71,723	65,864	205
14	Walden, *Jackson*	8	320		320	156,886	23,567	0	0
15	Wellington, *Larimer*	11	1,000		1,000	4,457,749	148,412	110,566	293
16	Total		13,390	5,820	19,210	32,021,616	1,121,192	1,519,358	

Line Number	Total Gas Production, Millions Cu. Ft.: To End of 1935	Total Gas Production, Millions Cu. Ft.: During 1934	Total Gas Production, Millions Cu. Ft.: During 1935	Number of Oil and/or Gas Wells: Completed to End of 1935	Number of Oil and/or Gas Wells: During 1935: Completed	Number of Oil and/or Gas Wells: During 1935: Abandoned	Number of Oil and/or Gas Wells: At End of 1935: Temporarily Shut Down	At End of 1935: Producing Oil Only	At End of 1935: Producing Oil and Gas[c]	At End of 1935: Producing Gas Only	At End of 1935: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1935, Number of Wells: Flowing	Oil Production Methods at End of 1935, Number of Wells: Pumping	Pressure, Lb. per Sq. In.[c]: Initial	Pressure, Lb. per Sq. In.[c]: Average at End of 1934	Pressure, Lb. per Sq. In.[c]: Average at End of 1935
1				5	0	0			3	1	4	2,940	2,920		3	600	200	100
2				51	0	0		7			7		2,000		7			
3				1,202	0	0		105			105		2,200		105			
4				15	0	0		11			11	4,560	4,535		11			
5	2,689	200	195	14	0	0	1			8	8		1,600		8	12	5	4
6				8	0	0		3		3				3				
7				12	0	0		12			12	3,880	3,860		12			
8	*y*	1,581	2,190	10	0	0			2	8	10	Sand	lenses		2	850	830	800
9				36	8	0		31			31	3,315	3,295	18	13			
10				33	0	1	8	3			3		375		3	25	12	12
11	19	0	0	6	0	0					0	1,004	960					
12				50	0	0	1	4			4		600		4			
13				17	0	0		15			15		2,600		15			
14				3	1	0	3	0			0	5,115	5,110					
15				30	0	0		22			22	4,500	4,480		22			
16				1,492	9	1		213	5	20	238			21	205			

[c] Footnotes for column heads and explanation of symbols are given on page 215.

South McCallum is a northwest-southeast-trending anticline with a minimum closure of 3400 ft. and embraces approximately seven sections of land within the closure area. The lowest exposed formation on the crest of the anticline is Pierre shale with the Coalmont formation of Eocene age on the flanks.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1935: Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Base[f]	Character of Gas, Approx. Average during 1935: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1935	Deepest Zone Tested to End of 1935: Name	Depth of Hole, Ft.
1			38.5	P	1,120	0.9	Hygiene	CreU	S	20	20	A	4	Lakota (CreL)	4,031
2			38.6	P			Pierre	CreU	H			MF	44		
3			31	P			Pierre	CreU	H			TS	1,097	Fountain (Pen)	1,875
4	37		34.8	P			Muddy-Dakota	CreU	S	12	25	A	4	Dakota (CreU)	4,995
5					1,131	2	Benton	CreU	H			D	6	Morrison (Jur)	1,392
6			42	P			Muddy	CreU	S	9	35	A	5	Lakota (CreL)	6,913
7			41	P			{Dakota	CreU	S	18[2]					
							{Sundance	Jur	S	14	20	D		Sundance (Jur)	4,490
8					1,080		Wasatch	Eoc	S	*y*	*x*	D		Mesaverde (CreU)	7,577
							Mancos	CreU	H			D			
9			37	P			Sundance	Jur	S	9	20			Sundance (Jur)	3,447
10			40	P			Mancos	CreU	S	*y*	*y*	T	22		
11					[1]		Santa Rosa (?)	Tri	S	22	44	D	2	Fountain (Pen)	2,000
12	52	43		P			Mancos	CreU	H			A	46	Weber (Pen)	7,173
13			35	P			Mancos	CreU	H			A	2		
14			50	P			Muddy-Dakota	CreU	S	14	90	AF	2	Morrison (Jur)	5,258
15			37.4	P			Muddy-Dakota	CreU	S	12	20	A	8	Morrison (Jur)	4,932
16															

[1] Inert; 7.9 per cent helium. At Thatcher, Colo., 11 miles distant, The Helium Co., of Louisville, Ky., has a $600,000 plant, temporarily shut down, for the extraction of helium from this gas.
[2] Figures from recovery indicate 20%+.

TABLE 2.—*Summary of Drilling Operations in Colorado*

Important Wildcats Drilled in 1935

	County	Location: Section	Township	Range	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day: Oil, U.S. Bbl.	Gas, Millions Cu. Ft.
1	Archuleta	24	33N.	2E.	1172	Mancos	Dakota	William E. Hughes Estate	500	
2	Moffat	22	12N.	100W.	2480	Wasatch	Wasatch	Mountain Fuel Supply Co.	140	
3	Jackson	34	9N.	78W.	5258	Pierre	Morrison	Continental Oil Co.	35	10(CO_2)

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1935	8	21
Number of oil wells completed during 1935	8	2
Number of gas wells completed during 1935	1	
Number of dry holes completed during 1935	4	

Chapter V. Refining

Engineering Progress in Petroleum Refining during 1935*

By Walter Miller,† Member A.I.M.E.

Any annual review of engineering progress in petroleum refining must of necessity include many features mentioned in earlier reviews. Advances do not spring mushroom fashion to wide acceptance overnight, but rather resemble rolling snowballs, gathering size and velocity as they progress. The new ideas of one year develop through the course of scattered adoption and testing during following years, to be ultimately discarded or to become an integral part of refinery engineering and operation.

Polymerization and Cracking

As an illustration, the publicity given to the polymerization and cracking of petroleum gases during the year has given many the impression that this is a new art. But patent and technical literature have disclosed active work on the problem dating back a decade or more and a unit capable of making 100 bbl. a day of polymer gasoline was constructed as early as 1930. Important strides have been made during 1935 looking to the more general commercialization of available processes, and some four important groups are furthering this work. In addition to the production of liquid products for inclusion as a constituent of commercial motor fuel, polymerization has also been a factor leading to the installation of a plant at the Houston refinery of The Shell Petroleum Corporation for manufacturing isooctane for aviation use, by making available dibutylene for catalytic hydrogenation Polymerization is not confined to unsaturated hydrocarbon gases as a source of raw material, and has been extended to include a preliminary decomposition of normal saturated gases under suitable heat and pressure conditions into the unsaturated types, which can then be used as raw material for the polymerization process.

Thus there is opened up the possibility of eventually using large quantities of natural gas in the manufacture of high-grade motor fuels, although the early commercial growth will be largely on cracking still gases for economic reasons. Such utilization will result in a somewhat lowered drain on crude-oil reserves and a partial elimination of the

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† Vice President, Continental Oil Co., Ponca City, Okla.

degradation or waste of an enormous quantity of natural gas, which now is necessarily produced as a by-product of crude-oil recovery far from fields of possible economic use. One authority has calculated a possible production of 30,000,000 bbl. a year from cracked refinery gases but this presupposes cracking all refinery gases, a condition that will never be reached because of other needs and uses, and it will probably be many years before a figure one-third as large will be attained.

Polymerization development and progress has been accomplished by the active groups in two principal directions: one, the use of high temperatures and pressures, and the other, the utilization of catalysts at comparatively low temperatures and pressures. It is unfortunate that already there are rumblings of rival patent combinations and threats of infringement litigation in the air, indicating possibilities of an unsettled condition similar to that existing in the cracking art for so many years.

Petroleum Gases

Automotive use of liquefied butane-propane mixtures is likewise a partial answer to the problem of how to utilize the heavier fractions of hydrocarbon gases from refinery and production activities. Authorities estimate the use of 8,000,000 gal. of butane as truck fuel in California, the area of greatest activity, in 1935, and there are signs that interest is expanding in other areas, particularly in some of those adjacent to refinery centers. The disadvantages of handling the highly volatile fuel in heavy high-pressure tanks in automotive transportation equipment may be offset by improved operating characteristics and the value, in the transportation of many perishable commodities, of the refrigerant qualities of the butane.

Interest in butane as a motor fuel has also been evident in the railway field. The weight limitations on fuel tanks are of less moment here and many installations are in use, although mostly in short-haul and switching work. Although the demand for the liquefied petroleum gases for use in internal-combustion engines is appreciable, the use of "bottle-gas" for various industrial purposes and for house and municipal gas plants still far overshadows it. Figures are not yet available for 1935, but the total volume is without doubt considerably in excess of the 42,000,000 gal. used in 1934.

Another important step in the progress being made to realize to the full the potential value of petroleum gases was the completion in March of the Carbon & Carbide Chemicals Corporation's $10,000,000 plant at Whiting, Ind., to utilize still gases from the refinery of the Standard Oil Co. of Indiana as raw materials in organic chemical manufacture. This marks an important advance toward realization of the dream long held by some, perhaps impossible of complete realization, that the petroleum industry

would in time equal or surpass the coal-tar industry as a source of raw material for industrial organic chemistry.

Truly 1935 can be called a gas year. Great progress has been made in some and some progress in all important branches of endeavor looking to extracting material of greater value from petroleum gases. The impetus gained will undoubtedly lead to many more interesting developments in the near future.

Lubricating Oil

In the lubricating-oil field, solvent-treating processes came in for further attention, following the trend that set in so strongly during 1933 and 1934. A number of new installations were made but there was a perceptible slowing up of the rate. This hesitancy is apparently due to the feeling of some refiners that the need of such highly refined oils has been exaggerated, and a questioning attitude as to whether such excessive refining did not remove also some beneficial constituents which the older processes left in the oil. It is quite possible that, once this last question is satisfactorily disposed of, the claims of those proponents of solvent treating that maintain that the economics favor the replacement of older treating methods will receive more favorable consideration. More active interest was evinced in solvent methods of dewaxing, although but few commercial units were built or contracted for. The fact that solvent-dewaxing processes successfully handle wax-containing petroleum products that are impossible for the older methods, while also accomplishing anything that the orthodox pressing and centrifuging methods are capable of, undoubtedly gives the newer process an advantage in new installations. There is a difference of opinion, however, as to whether the advantages are sufficient to warrant replacing existing installations of the older methods.

Some investigations are being made of the possibilities of solvent action in the separation of lubricating stocks into a number of sharply defined fractions, by a step-wise treatment with solvents of different characteristics. Successful solution of the problems may bring solvent separation into competition with more orthodox distillation processes. Another application of solvent treatment undergoing present development is the acid treatment of lubricating oils at low temperatures in propane solution. In effect, this combination of sulfuric acid and propane is an application of a two-solvent refining system in which the peculiar solvent qualities of sulfuric acid at low temperatures are utilized without incurring the high losses incident to the usual acid treatment. This seems to be a sequel to the method developed some years ago for the low-temperature acid treatment of cracking-process distillates.

Automotive and aircraft engine design is making increasing demands upon the refiner to furnish lubricating oils with greater oiliness and ability

to resist extreme pressures. As previously noted, the addition of oleic acid under the Wells-Southcombe patents has been practiced to a limited extent in this country since 1923, and in later years the addition of oxidized products of various types was also practiced to a small extent. But the increased speeds, higher temperatures and higher bearing pressures involved the further step in motor design of bearing materials of special alloys, which in turn called for oiliness, extreme pressure, and low corrosion characteristics for the most satisfactory lubrication, to a degree not possessed by straight petroleum oils. Widespread research activities attested the importance given to this problem by the petroleum industry, and papers and discussions at the meetings of the American Petroleum Institute during the year indicated how extensively the subject was being studied. One large company for about a year has marketed lubricating oils with a phosphate-compound addition agent; another company has been marketing successfully for more than two years lubricating oils using dichlor methyl stearate as the addition agent for improving these characteristics and a third organization, on a much smaller scale, has had considerable success with the use of an addition agent of the chlorinated aromatic ether type. Much further development and progress can be expected in the near future. The swing to motor lubricants of lower viscosity, observed in 1934, continues, although at a somewhat reduced rate.

Motor Fuel

Hydrogenation by catalysis in connection with polymerization at low pressure resulted in the production of isooctane, as noted previously. No other major hydrogenation developments in this country were noted. In Europe, however, coal hydrogenation received a great impetus with the completion and initiation of operation of the Imperial Chemical Industries plant in England.

Large-scale combination topping and cracking units for motor-fuel production continue to replace obsolete types of equipment. The Humble Refining Company's 33,000-bbl. unit at Baytown, Texas, is reputedly the world's largest installation. A projected second unit of 30,000 bbl. capacity at the Texas City refinery of the Pan American Petroleum Co. is also indicative. The trend toward tube stills for efficient heating is shown by recently released Bureau of Mines figures, which disclose that 55.7 per cent of the crude-running capacity of the United States was represented by pipe-still installations at the end of 1934.

Worth noting here is the decision of the U.S. Supreme Court refusing to review the lower court's decision in the case of Universal Oil Products v. Root Refining Co., the effect being to make final the decision of the District Court and the Court of Appeals validating Universal's patents on clean recirculation and multi-coil cracking. This is another important

step in the clarification of the cracking-patent situation and probably will have some effect in directing new installations into organized patent-protected channels.

The number of new cracking installations, including the combination units noted above, was not abnormally large during the year, but there is a great deal of activity in contemplation and the licensing and construction companies have a large number of projects on the board and in prospect. A few installations were made for reforming straight-run gasoline, although nothing like the activity exhibited in 1933 and 1934 was shown. Two factors indicate possibilities for greater activity in the future; first, the higher price levels attained by natural (casinghead) gasoline, and second, polymerization installations providing a more remunerative outlet for the large quantities of cracked gases obtained as a by-product. Some influence in the other direction, however, will be exerted by a further lowering in the cost of tetraethyl lead to the refiner, and the raising of the permissible limits from 1½ c.c. to 3 c.c. per gallon in motor gasoline.

Stabilization of gasoline both in the refinery and in the natural-gasoline plants is a process almost universally adopted. The application of stabilization to crude petroleum is more unusual. A noteworthy installation being made is a unit of 44,000 bbl. daily capacity at the Houston refinery of Shell Petroleum Corporation for removing the lightest fractions from the East Texas crude as received from the field. A small installation for stabilizing the highly volatile Rattlesnake crude oil has been operating in New Mexico for about eight years.

Of interest in gasoline treating is the combination in a large unit, now being designed for immediate erection in a California refinery, of the method of low-temperature acid treating of high-sulfur-content cracking-still distillate (Halloran process) with the multistage short-time contact centrifugal operation (Stratford process). Exhaustive experimental work had proved that the advantages of both could be obtained in one operation at a material saving in construction as well as in operating cost and with lower losses by degradation and as sludge.

The national control of gasoline production under Petroleum Code authorities, which so successfully reduced stocks of motor fuel to a reasonable level during 1934, was discontinued as a result of the Supreme Court decision abolishing code authorities. Considerable apprehension was felt when this took place, but apparently the industry had concluded that good business practice forbade the return to the old method of carrying stocks greatly in excess of those justified by economic conditions. Lower stocks, by approximately 700,000 bbl. on Oct. 31, 1935, compared with 1934, although perhaps in part due to rather greater increase in consumption than anticipated, is gratifying proof of the ability of the industry to keep stocks at a reasonable level. Illicit refining of hot oil in the East Texas district, although not entirely eliminated, is apparently

being well controlled and no longer constitutes the menace that formerly it presented.

Further development of Diesel engines and extension of their use occupied much attention from both the refiners and the automotive industry. Diesel-electric power for locomotives is exemplified in the Santa Fe railroad's "Super Chief," designed to haul the heavy passenger equipment. The establishing of a record of 137 miles per hour by a Diesel-powered car at Daytona Beach shows the trend in the direction of broader use of the high-speed Diesel engine, although the commercial application to automotive equipment was practically wholly in the trucking field, where heavy duty, particularly hill-climbing ability, is an important factor. The supplying of satisfactory Diesel fuel is a problem still in a state of flux. The need for the highest attainable freedom from foreign matter in the fuel to prevent undue wear of the closely fitted fuel injection equipment led to the rather wide installation of centrifuge equipment. However, there is still divergence of opinion as to the special characteristics that an ideal Diesel fuel should possess, and the importance to be given distillation range, cetane number, etc., waits for future developments.

Taken as a whole, the year has presented a great deal that is interesting and has given ample proof of the alertness and progressiveness of the individuals making up the refining branch of the petroleum industry.

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NOTE: In this index the names of authors of papers and discussions and of men referred to are printed in SMALL CAPITALS, and the title of papers in *italics*.)

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